Micromegas detector development for thermal neutron detection

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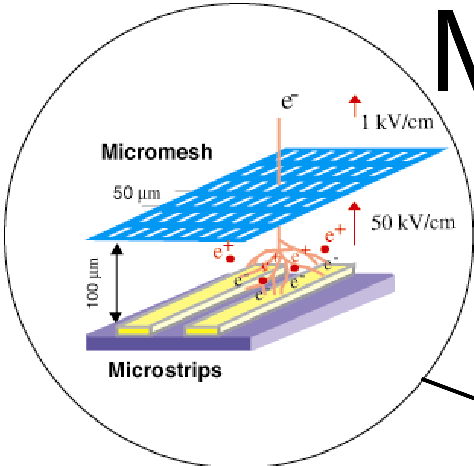
Contents

- A large high-efficiency multi-layers Micromegas thermal neutron detector (***NMI3***)
- Concept – technology – design – simulations (electric field configurations, thickness optimization) – tests/set up at CEA – simulations vs data – measurements at Orphée reactor
- Towards ***SINE2020*** :
- Implementing microbulk technology
- Simulations – design – build of a prototype
- A multi-microbulk detector
- Summary + future plans

Micromegas with ^{10}B layers

- *Due to the so-called **^{3}He shortage crisis**, many detection techniques used nowadays for thermal neutrons based on alternative converters.*
- *Thin films of **^{10}B or $^{10}B_4C$** are used to convert neutrons into ionizing particles which are subsequently detected in gas proportional counters but only for small or medium sensitive area so far.*
- *The micro-pattern gaseous detector **Micromegas** has been developed for several years in Saclay and is used in a wide variety of neutron experiments combining high accuracy, high rate capability, excellent timing properties and robustness. We propose here a **large high-efficiency Micromegas-based neutron detector with several $^{10}B_4C$ thin layers** mounted inside the gas volume for thermal neutron detection.*
- *The principle and the fabrication of a **single detector unit prototype** with overall dimension of ~ 15 x 15 cm^2 and a flexibility of modifying the number of layers of $^{10}B_4C$ neutron converters are described and simulated results are reported, demonstrating that typically five $^{10}B_4C$ layers of 1-2 µm thickness can lead to a detection efficiency of 20-40% for thermal neutrons and a spatial resolution of sub-mm.*
- *The design (**bulk/microbulk**) can be well adapted to large sizes making possible the construction of a mosaic of several such detector units with a large area coverage and a high detection efficiency, showing the good potential of this novel technique.*

Micromegas concept

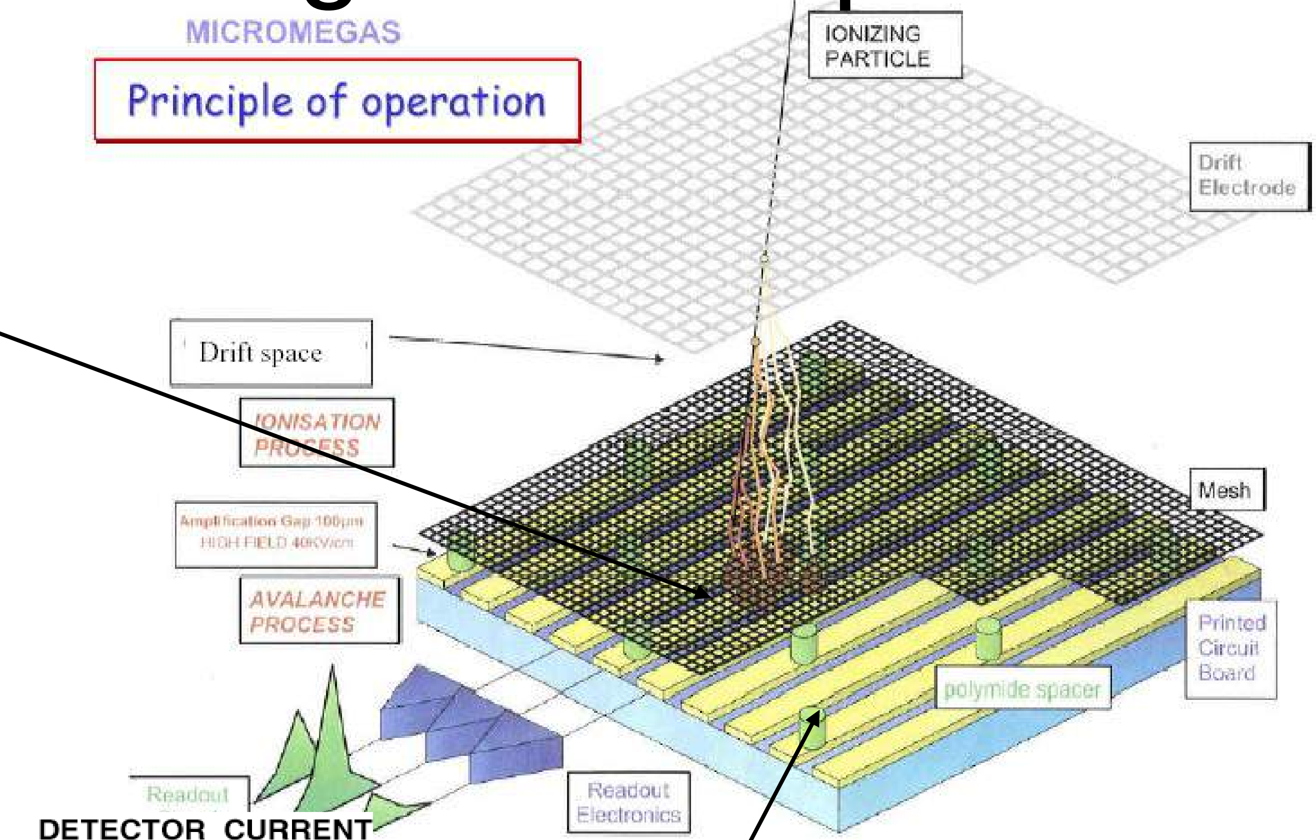


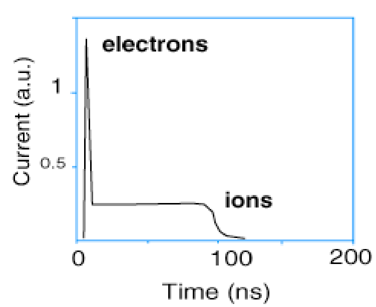
Two-region gaseous detector
separated by a Micromesh :

- Conversion region
  - Primary ionization
  - Charge drift towards A.R.
- Amplification region
  - Charge multiplication
  - Readout layout
  - Strips (1/2 D)
  - Pixels

==>Very strong and uniform E.F.

- simplicity
- single stage of amplification
- fast and natural ion collection
- discharges non destructive





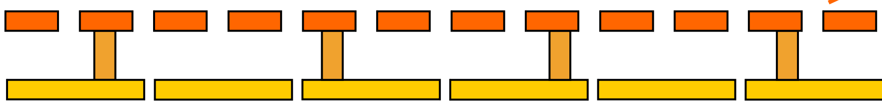
keeping the gap constant ~100 µm gap

- **Ni or Cu micromesh + pillars on PCB**
- **Self-supported copper micromesh**
- **« bulk » and « micro-bulk » technologies**
- **Recent InGrid techniques** : mesh over Si pixel chip

Micro Mesh Gaseous Structure, Y. Giomataris, Ph. Rebourgeard, J-P Robert and G. Charpak, NIM A376, 1996, p29 (CEA-biospace patent)

Bulk technology

Readout plane + mesh all in one

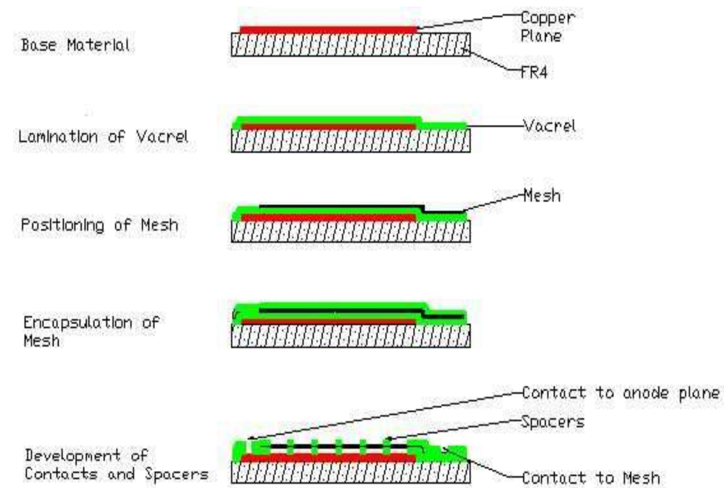


Woven Inox mesh 30 µm

vacrel 128 µm

Readout pads

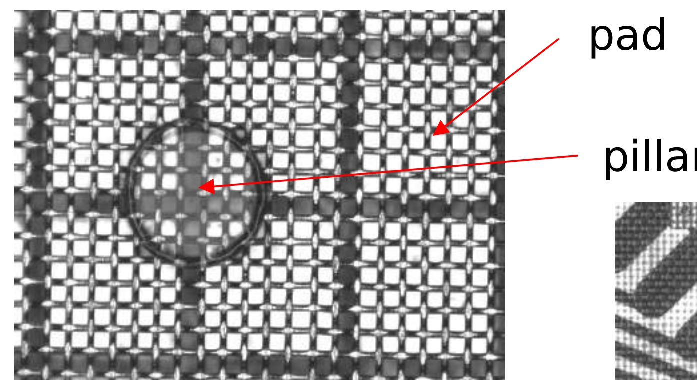
Well established technique (lamination)

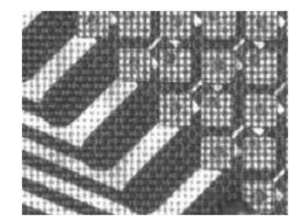


<u>Bulking</u>: Process to encapsulate the mesh on a PCB (*mesh = stretched wires*)

The pillars are attached to a woven mesh and to the readout plane (PCB)

Typical mesh thickness 30 µm, gap 128 µm

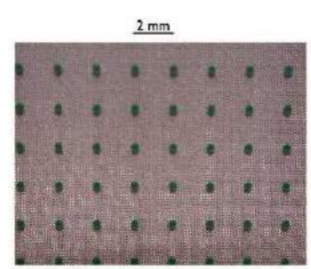


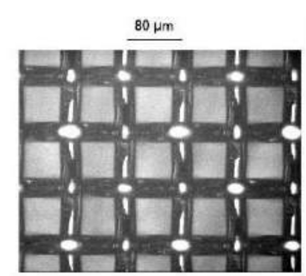


Uniformity, robustness, low cost, no supporting frame,

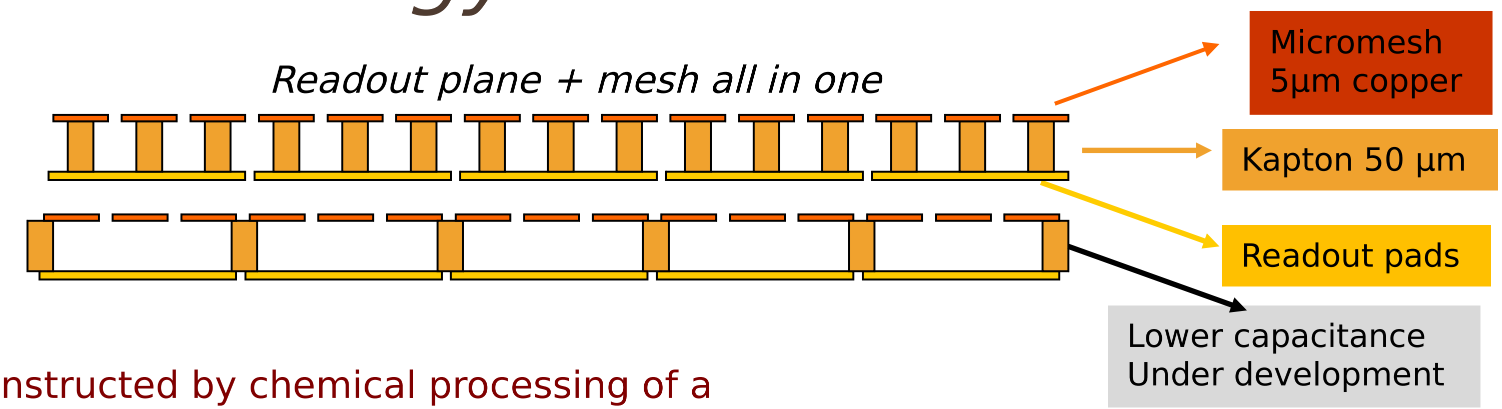
- ✓ **Very small dead zone area on the edges**
- ✓ **Enables stack for large surfaces**
- ✓ **Easy fabrication**
- ✓ **Mass production!**
- ✓ **Ideal gap for Ne/He - based mixtures**

- ✘ Good but limited energy resolution due to woven mesh (~18% @ 6keV)





Microbulk technology

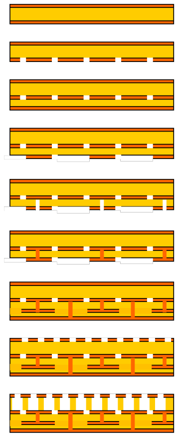


Microbulk Micromegas

The pillars are constructed by chemical processing of a kapton foil, on which the mesh and to the readout plane are attached. ***Mesh is a mask for the pillars!***

Typical mesh thickness 5 µm, gap 50/25 µm

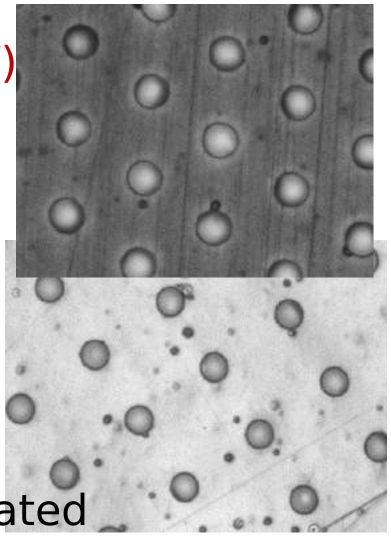
- Kapton foil (50 µm), both side Cu-coated (5 µm)
- Construction of readout strips/pads (photolithography)
- Attachment of a single-side Cu-coated kapton foil (25/5 µm)
- Construction of readout lines
- Etching of kapton
- Vias construction
- 2nd Layer of Cu-coated kapton
- Photochemical production of mesh holes
- Kapton etching
- Cleaning



All advantages of a bulk Micromegas & enhanced performance

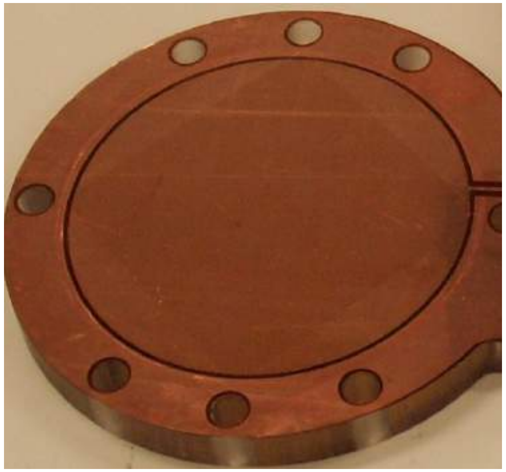
In addition:

- ✓ **Low intrinsic background**
- ✓ **Energy resolution** (<11% FWHM @ 6 keV)
- ✓ **Low mass detector**
- ✓ **Very flexible structure**
- ✓ **Less outgassing**
- ✓ **Robustness** (temperature, mechanical stress)



But:

- ✘ Higher capacitance
- ✘ Fabrication process of 2D readouts complicated



Design of a high-efficiency Micromegas neutron detector

***Aim**: to build a large area thermal neutron detector ($1m^2$) based on Micromegas at a reasonable price (<100k€) with a high efficiency of detection (>50% at 25meV), a spatial resolution of the order of 2x2mm, a time resolution for the tagging of the neutron of the order of 1 µs and a max counting rate of the order of $1e^6$ neutron/sec.*

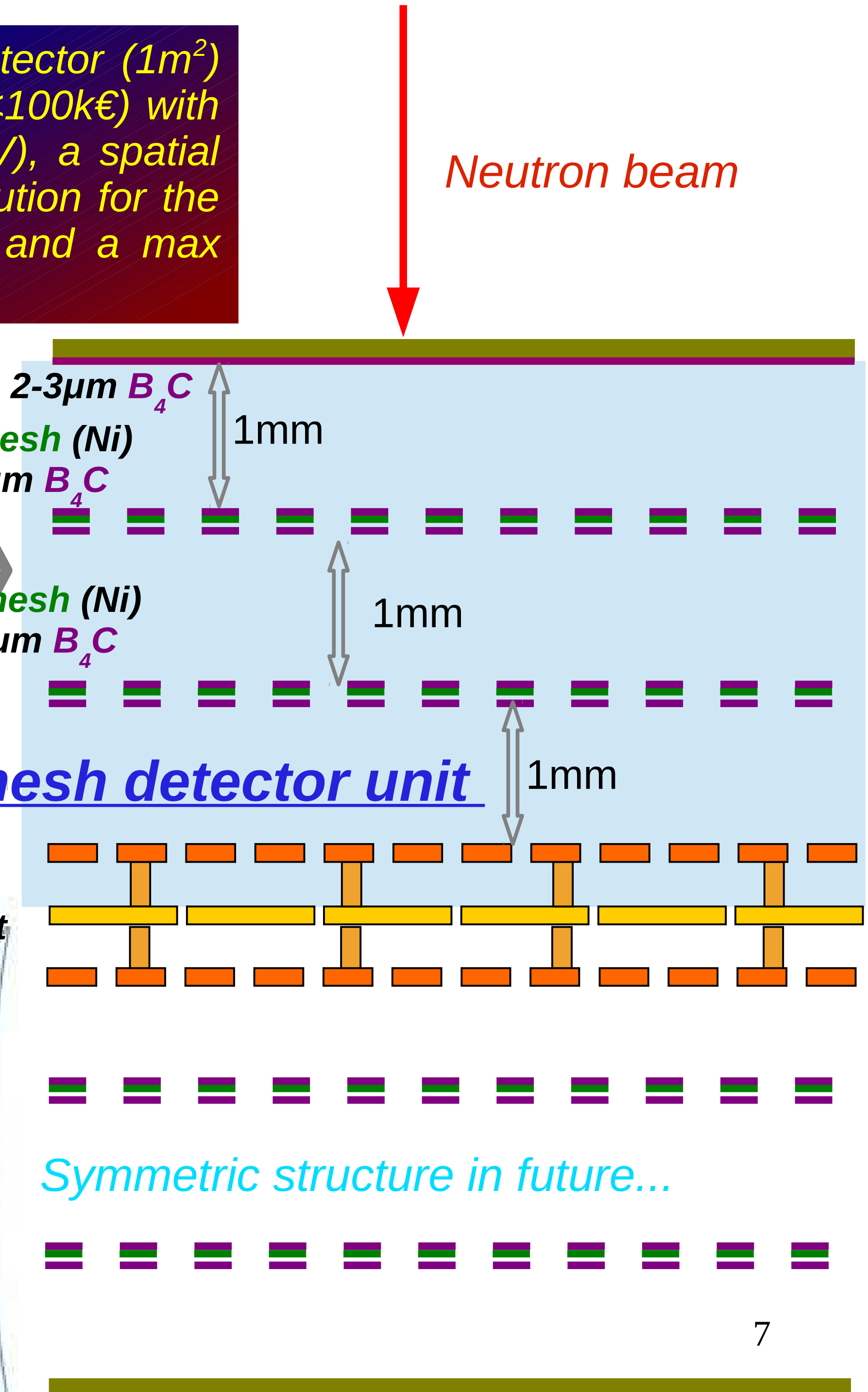
Design of a single unit

- tests to be done on a small surface (7 x 7 cm^2), single sided structure.
- 1-2cm thickness (stack of 2)
- With with 5 x $^{10}B_4C$ layers
- With bulk-micromegas technology

- ***Cathode 20µm Al with 2-3µm B_4C***
- ***Micromegas woven mesh (Ni) with 2 double-sided 2-3µm B_4C***
- ***Micromegas woven mesh (Ni) with 2 double-sided 2-3µm B_4C***

A single 2-mesh detector unit

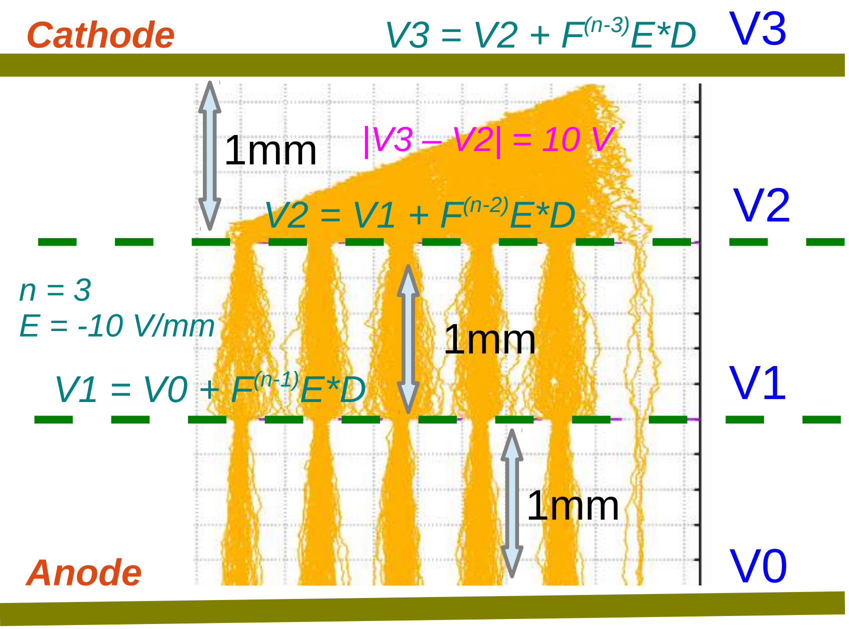
- ***Anode Cu***
- ***PCB + readout***



Back-to-back Structure

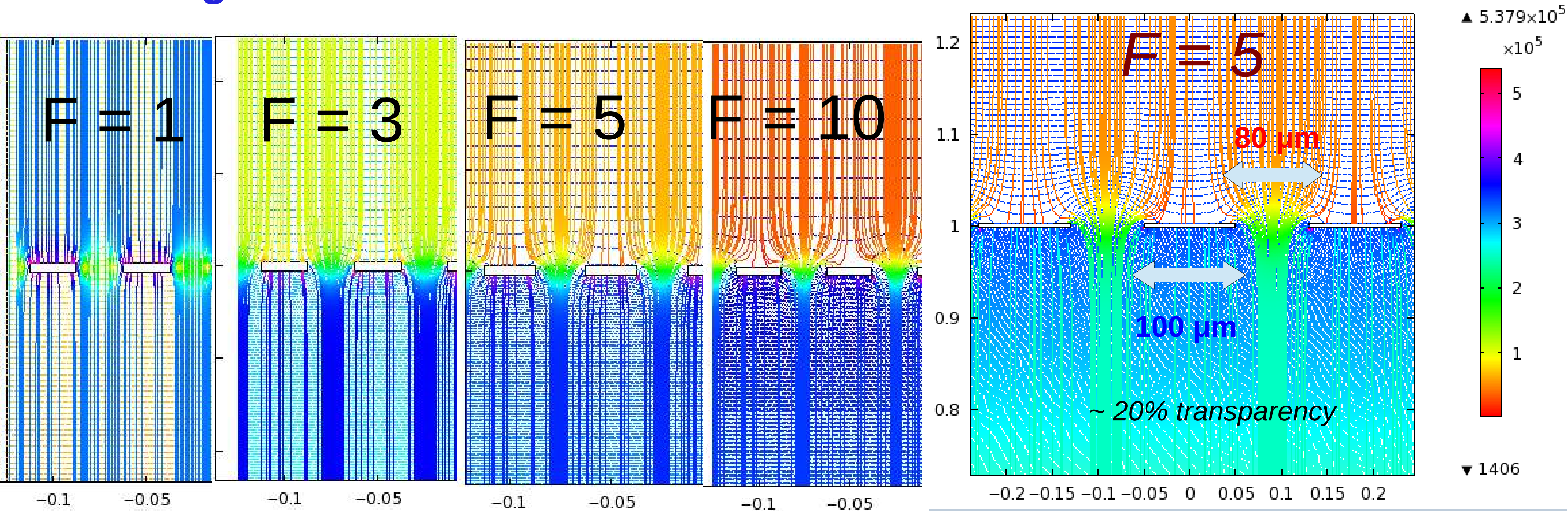
Many modules can theoretically be stacked for >50% efficiency

Electric field configuration – COMSOL simulations



F	*1*	*3*	*5*	*7*	*10*
V3 (V)	-330	-430	***-610***	-870	-1410
V2 (V)	-320	-420	***-600***	-860	-1400
V1 (V)	-310	-390	***-550***	-790	-1300
V0 (V)	-300	-300	***-300***	-300	-300

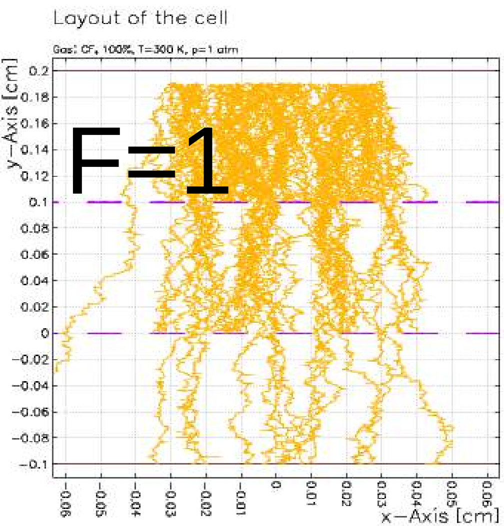
A single 2-mesh detector unit

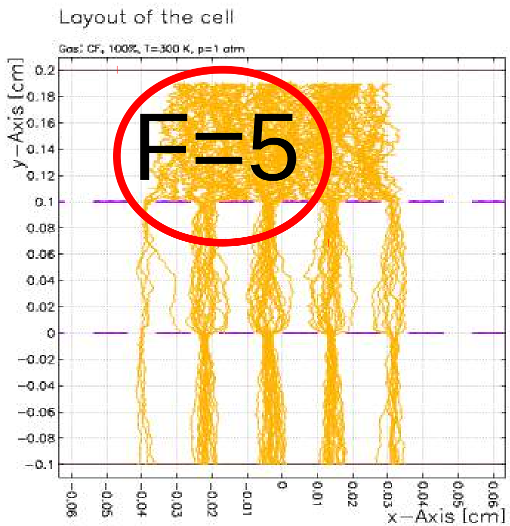


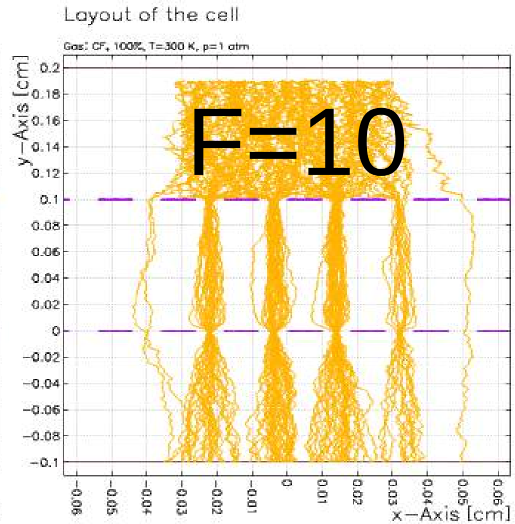
Electrons collection efficiency (E.C.E.) – Garfield simulations

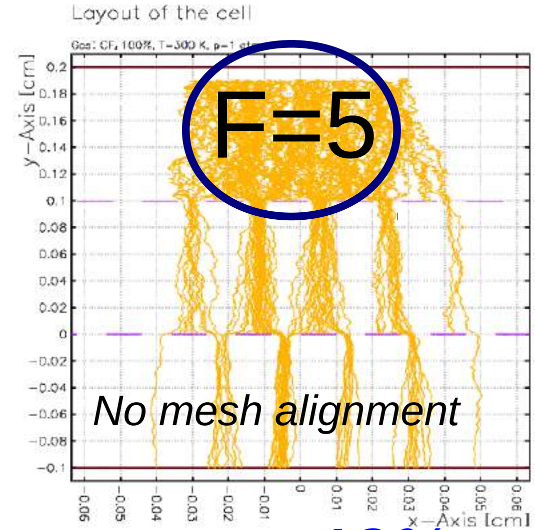
Bar: 0.01 cm
Hole: 0.008 cm

Gas: CF_4

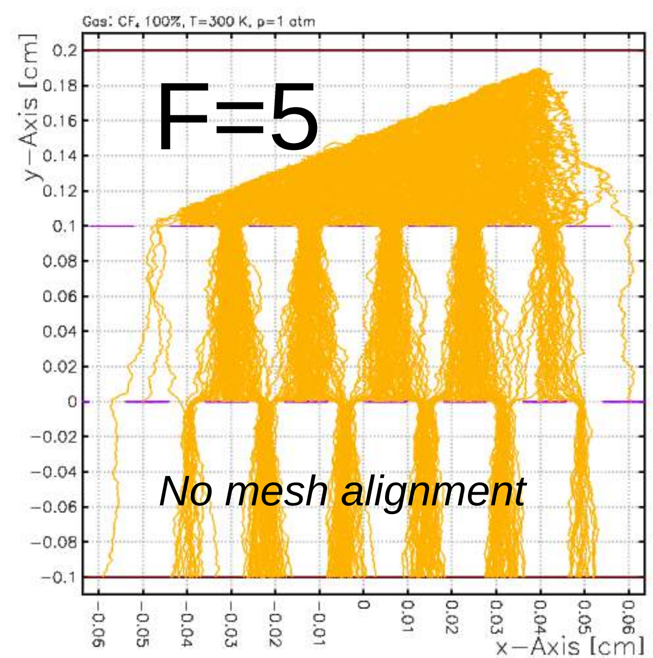




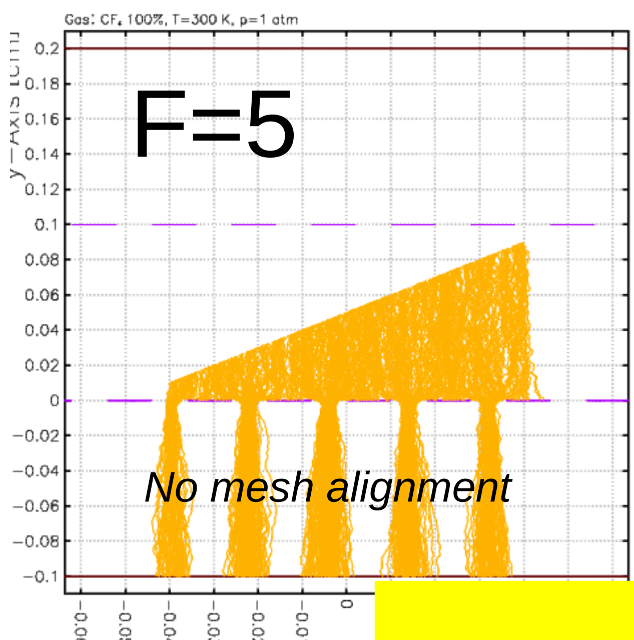




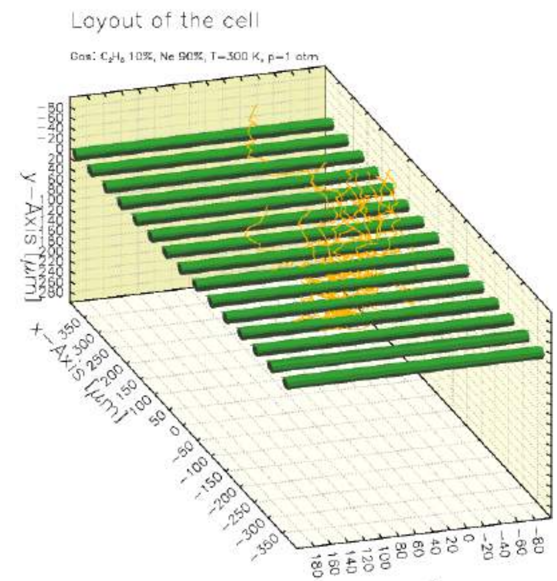
E.C.E. : *15%* *75%* *100%* *48%*



48%

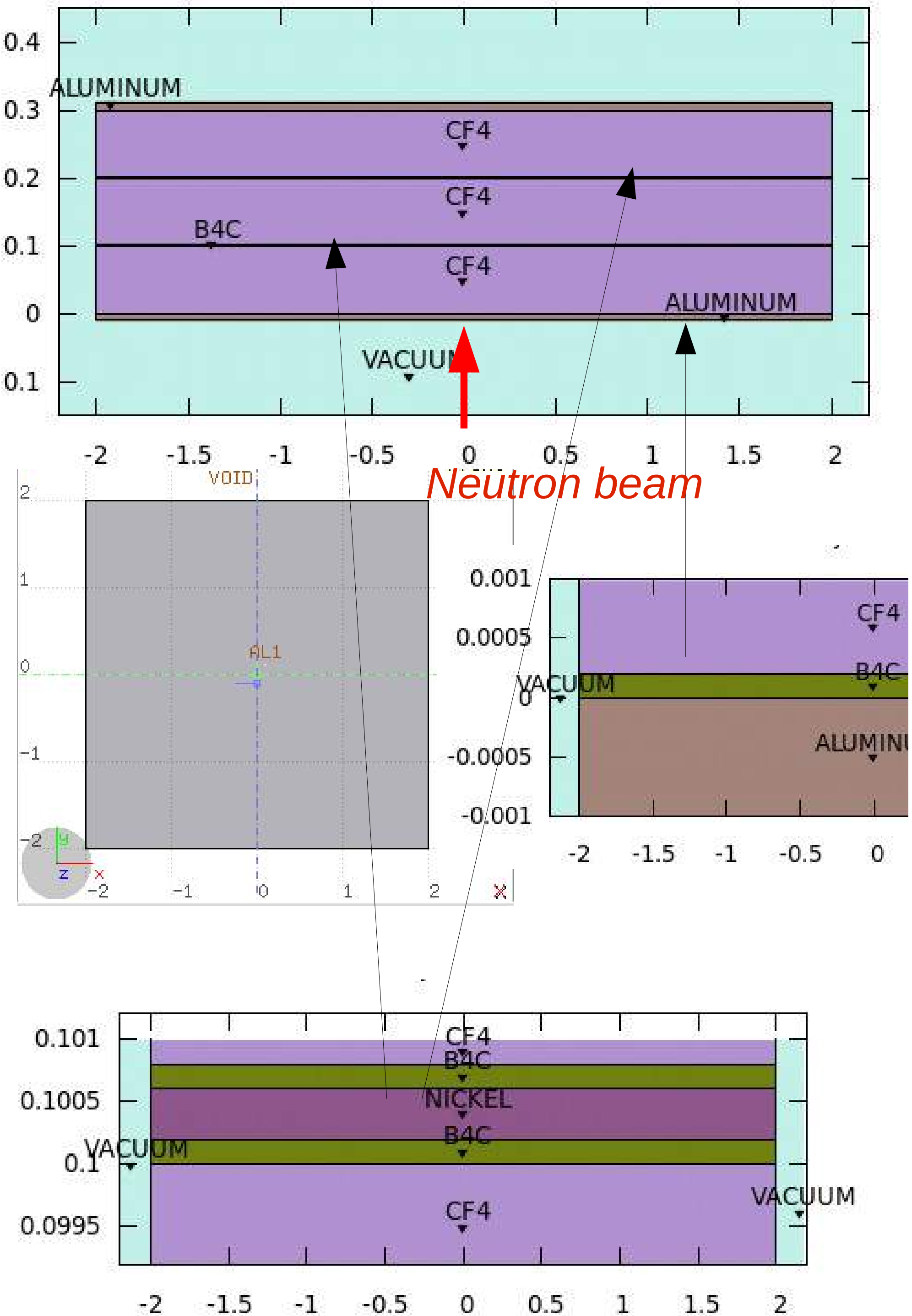


77%



CF_4: high electron collection efficiency (small diffusion), good performance at high voltages

Thickness optimization of a B_4C layer using FLUKA MC



- In ***FLUKA MC*** transport and interactions of neutrons with energies below 20 MeV are handled by a dedicated library.
- α and ^{3}H fragments from neutron capture in ^{6}Li and ^{10}B can also be transported explicitly (point-wise transport).

Simplified geometry of a Micromegas prototype

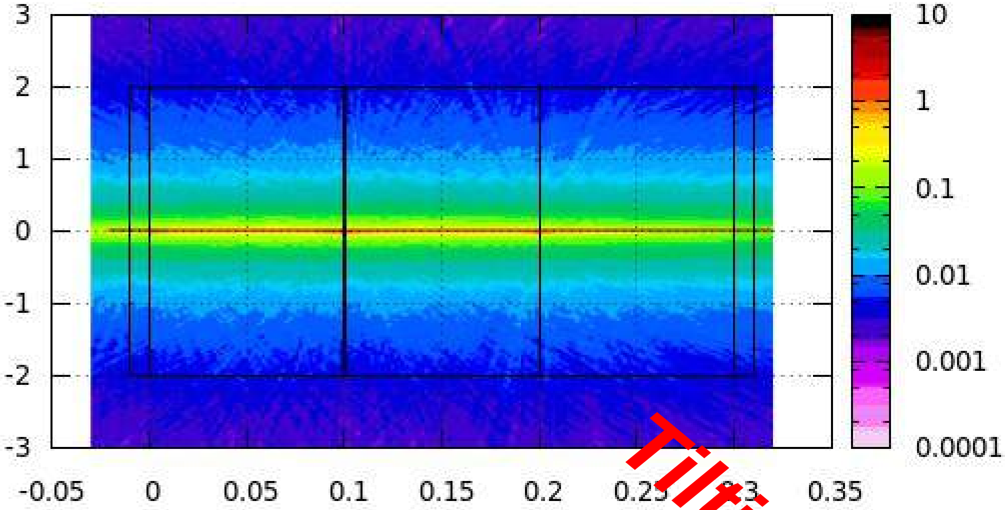
- Al end plates 4 x 4 cm: 0.1 mm
- 2 mesh of Nickel: 4 μm
- 3 Gas layers CF_4: 1 mm
- 5 layers of converter B_4C: 0.1-5 μm
- Neutron beam of (0.025, 0.01, 0.1, 1 eV) pencil-like parallel to z-axis
- Energy Deposition is scored at the gas volumes
- Detection thresholds at: (1, 5, 10, 100 keV).

Prototype with 5 x $^{10}B_4C$ layers

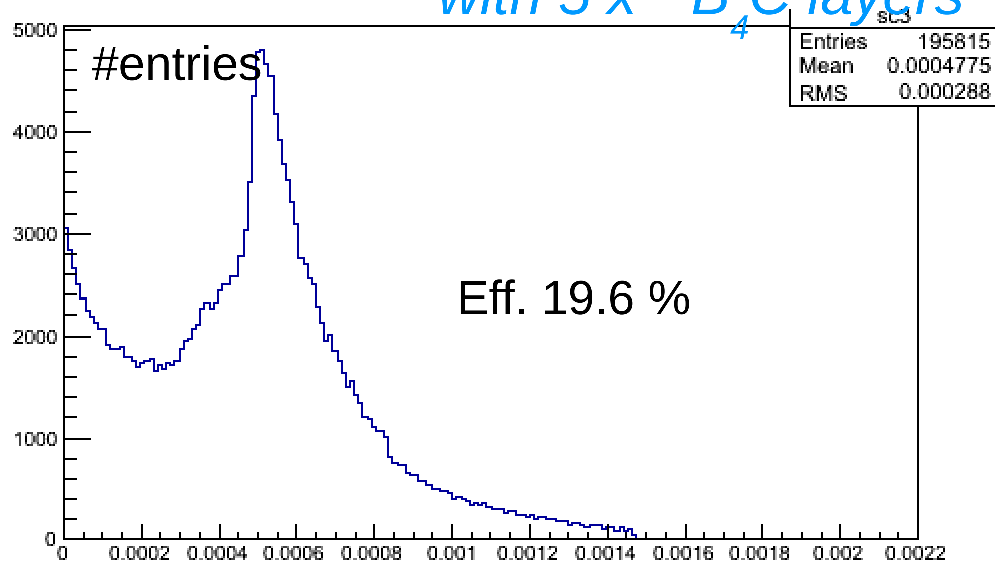
Event-by-Event E deposition spectra: beam on the Al frame with

En = 0.025 eV, Eth = 1 keV, 2μm B_4C, 1E6 primaries

with 5 x $^{10}B_4C$ layers



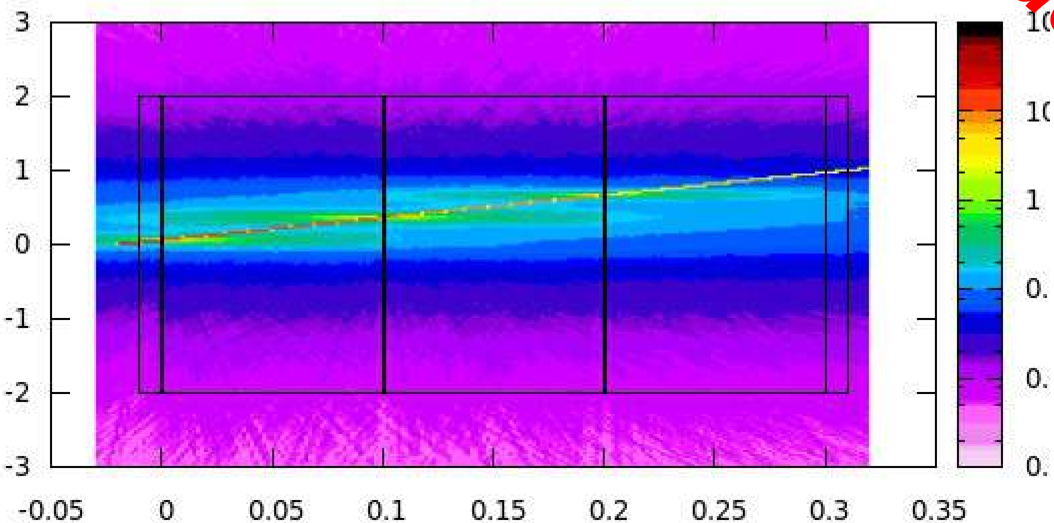
Spatial distribution of ALL-PART fluence (tracklength density) normalized to particles/cm^2/primary

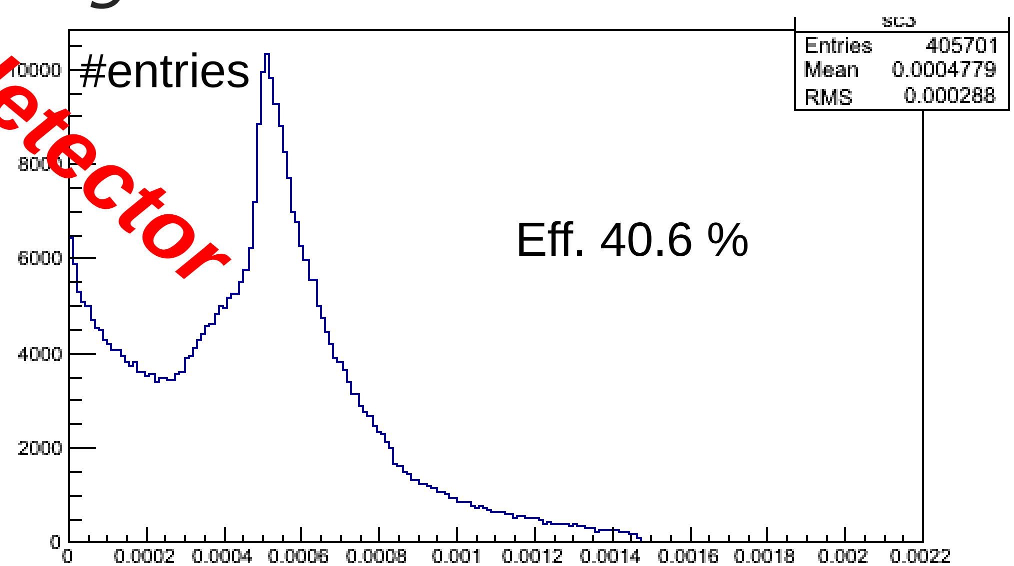


Tilting the detector

using FLUKA MC

Perpendicular



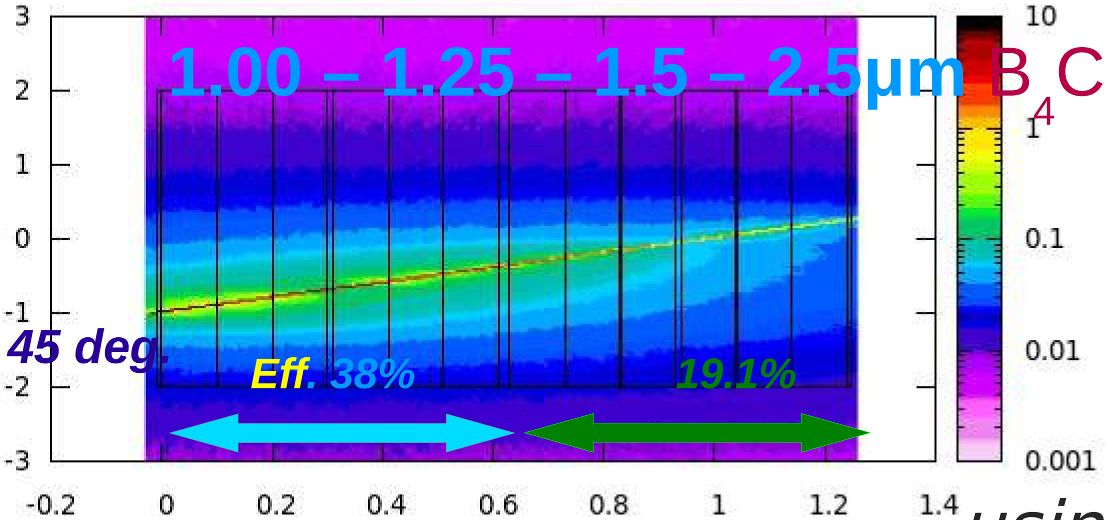


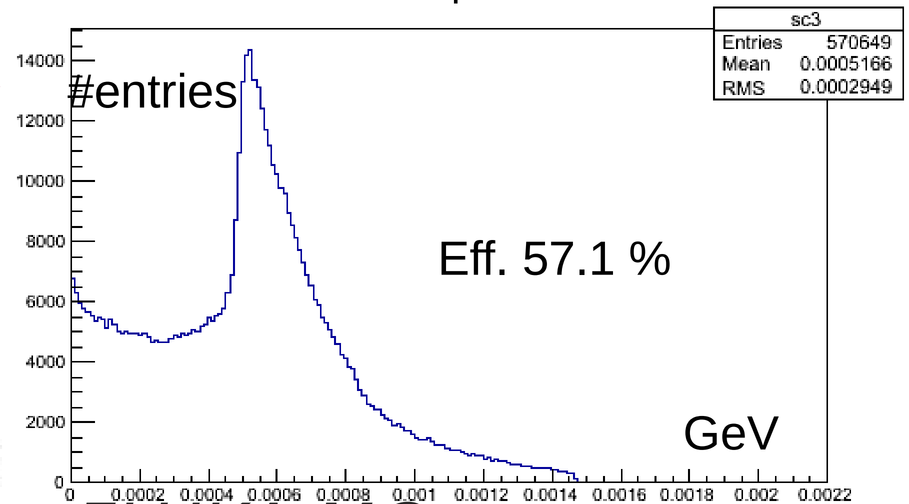
Direction cosine of beam with y-axis: 0.95 => 71.8 deg.

A “single 2-mesh detector unit”

- 2-3 μm of B_4C gives the best efficiency
- Can record neutron efficiencies for thermal neutron beam energies (perpendicular beam) ~ ***20%***
- The aim is to build a detector capable of **> 50%** efficiency

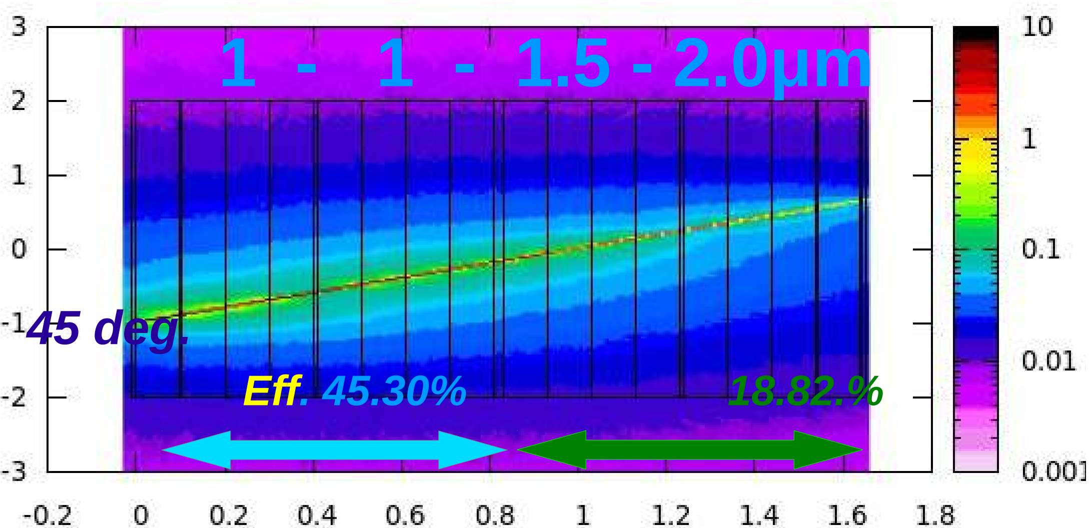
A “2-double 2-mesh detector unit” (20 B_4C layers)

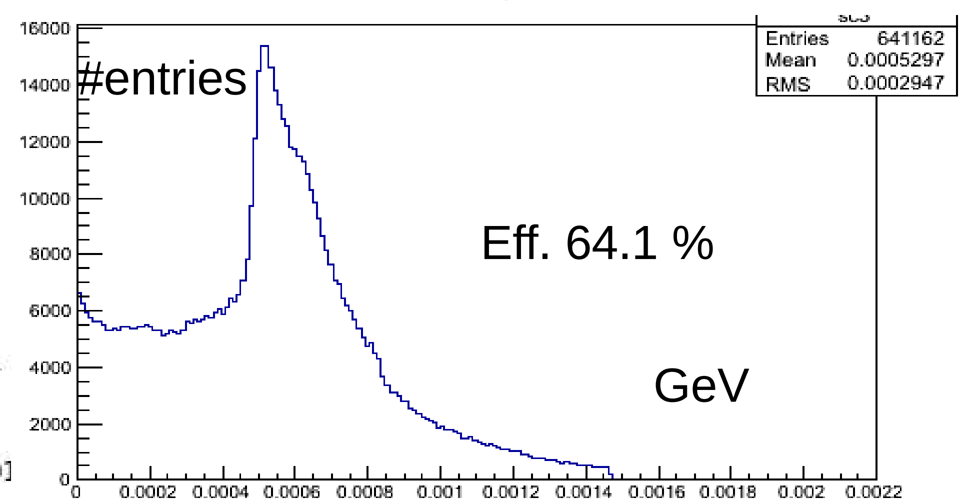




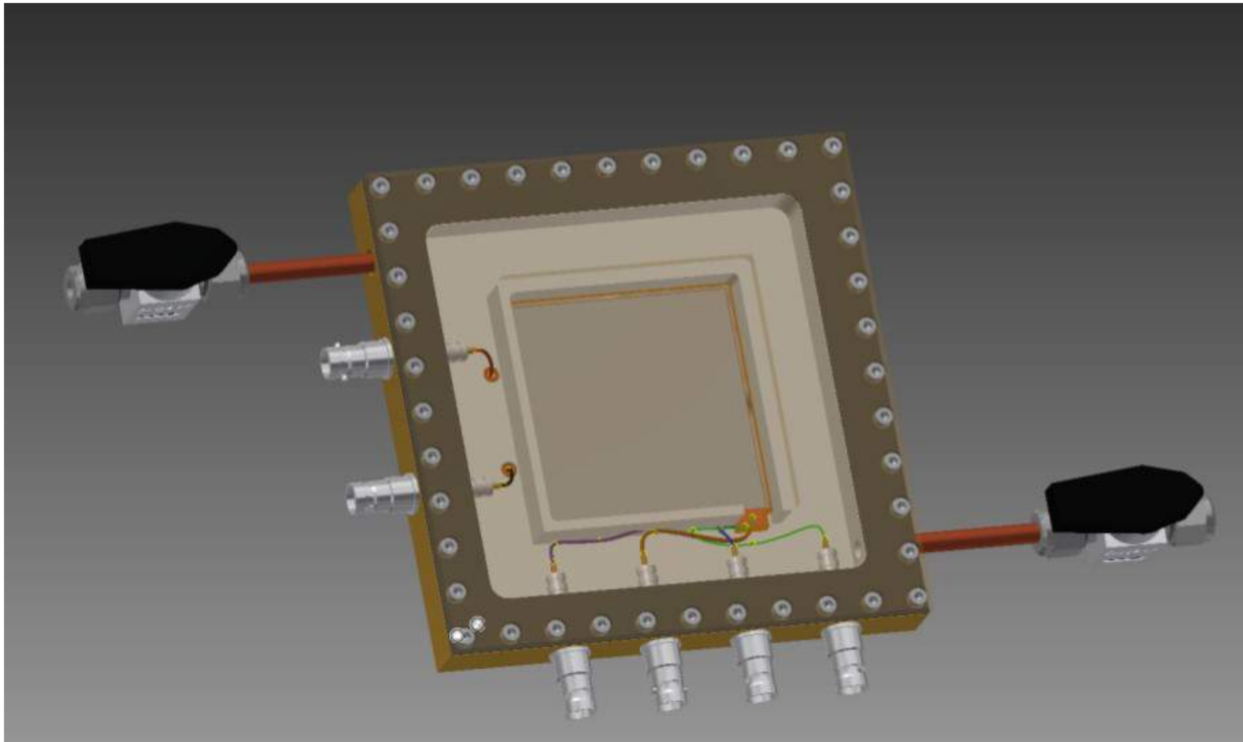
using FLUKA MC

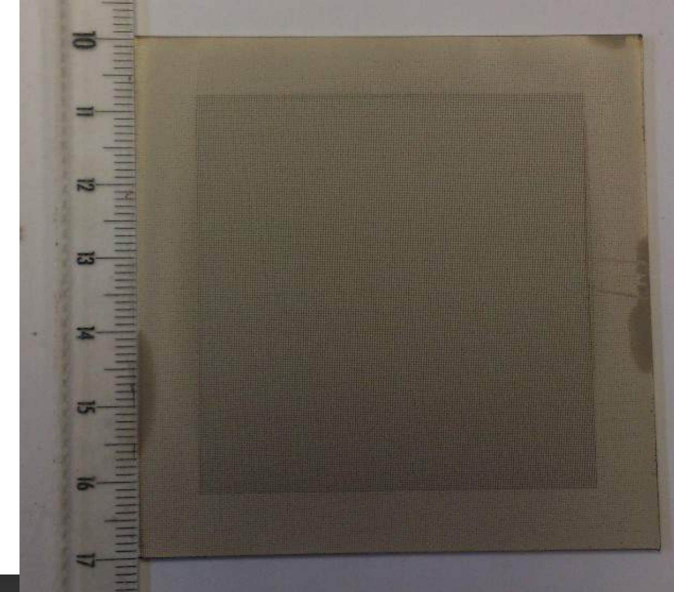
A “2-double 3-mesh detector unit” (28 B_4C layers)



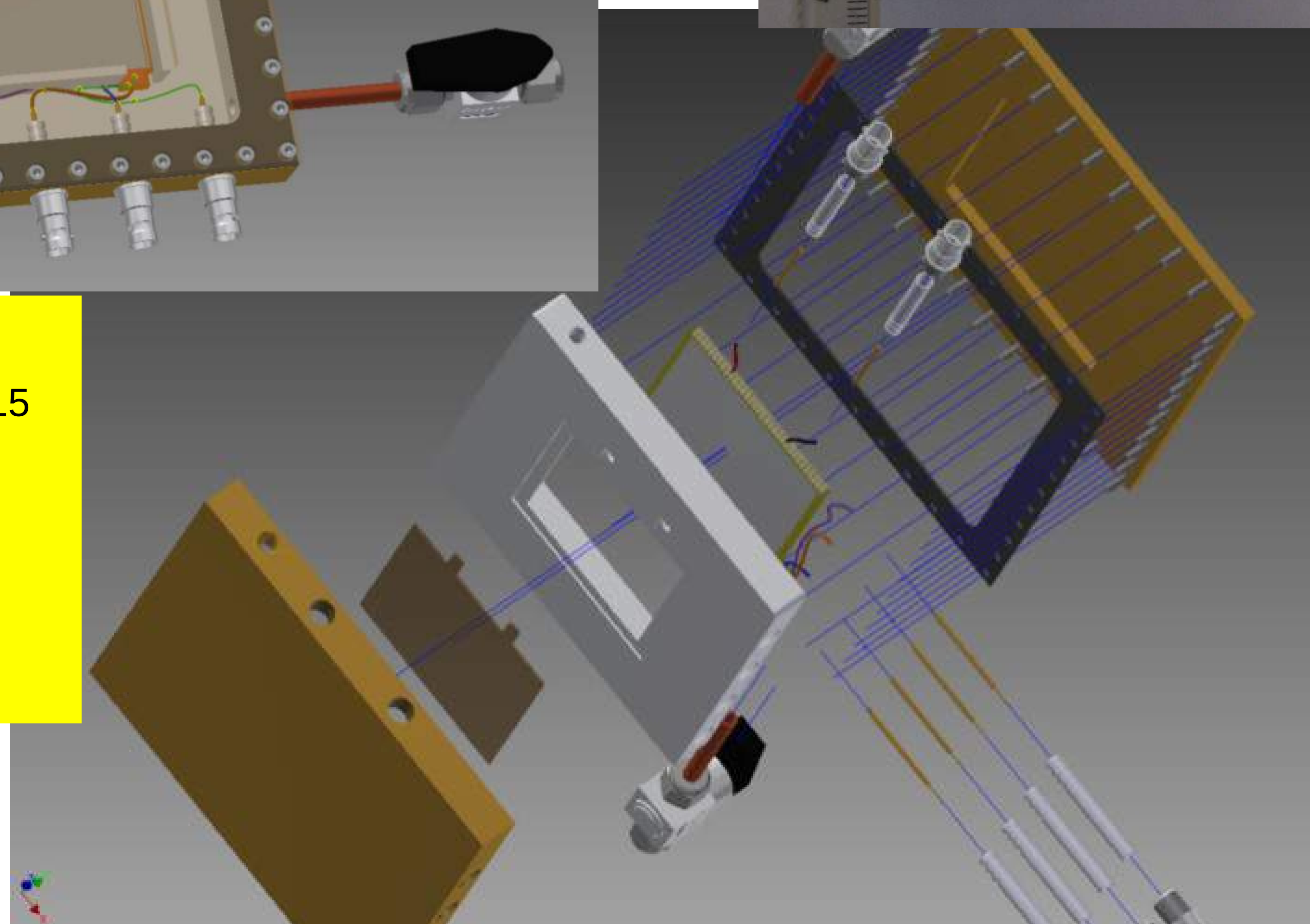


Design of the prototype

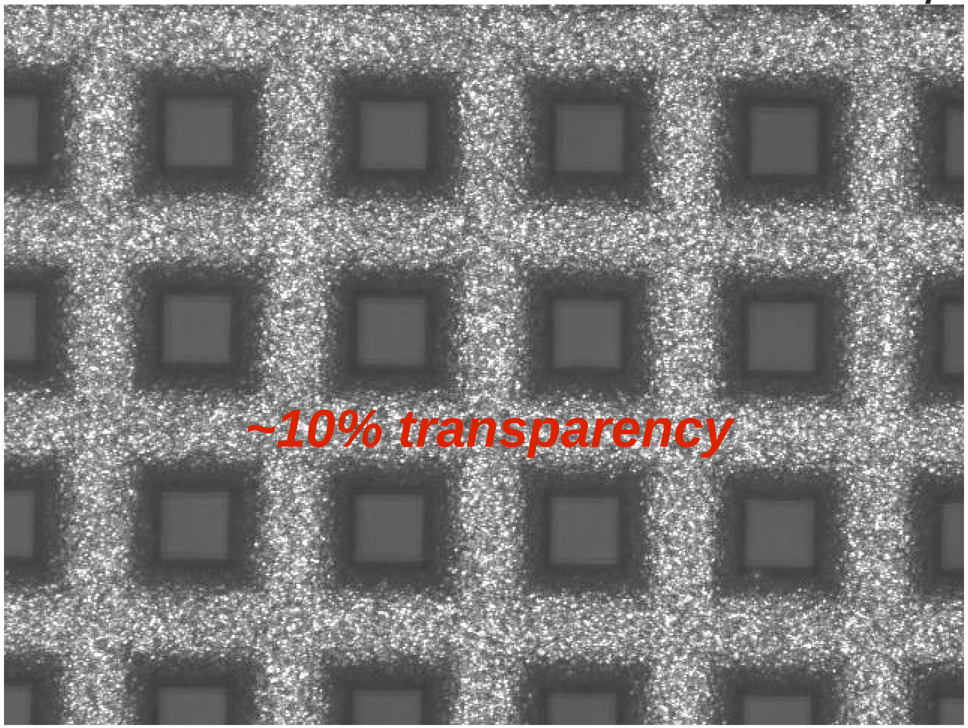


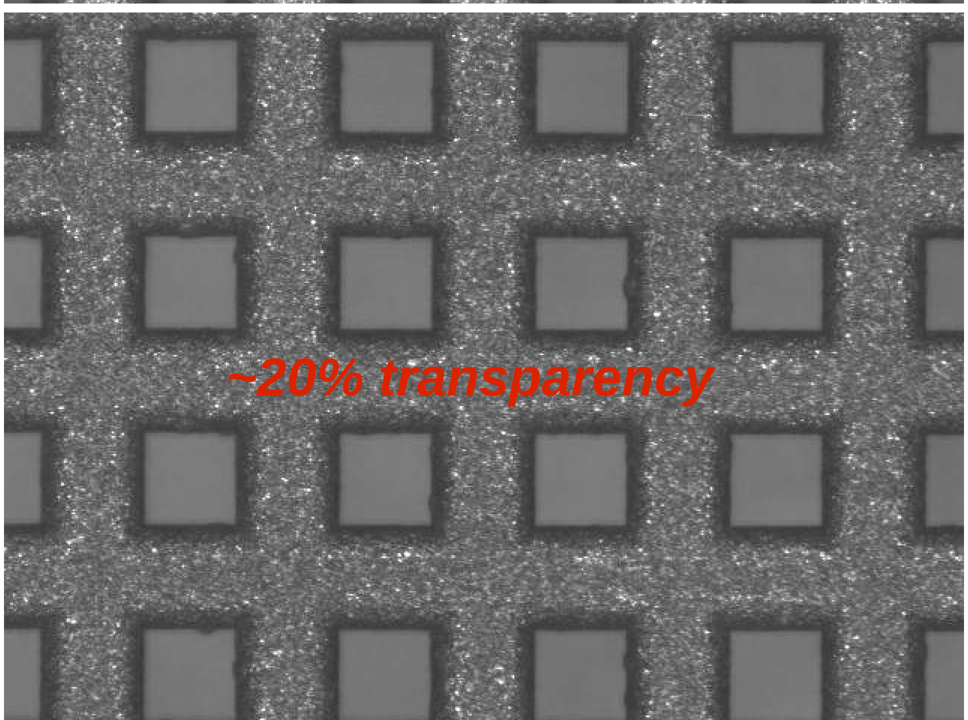


- Overall dimension: ~ 15 x 15 cm^2
- Frame: 7 x 7 cm^2
- Active zone: 5.4 x 5.4 cm^2
- Mess thickness: 4 μm



Meshes for $^{10}B_4C$ layer production





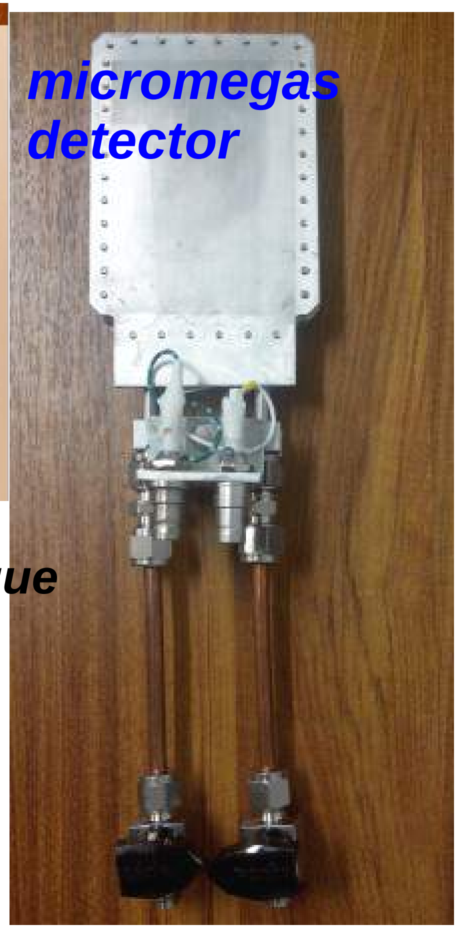
Several 70x70 mm^2 , 1 mm thick, stainless steel frames, on which are stretched (made by electroforming) 2 types of Nickel mesh:

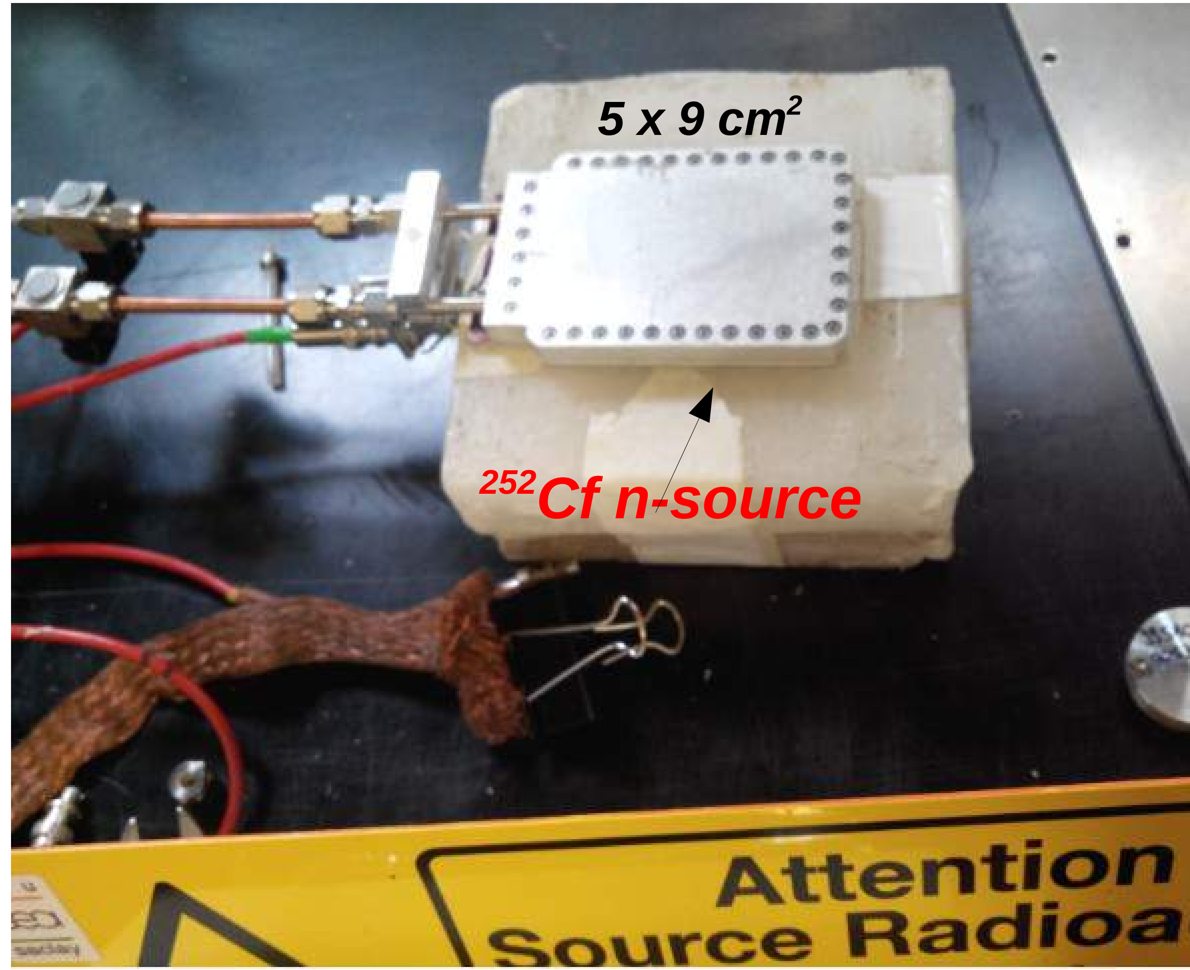
- 10% optical transparency
- 20% optical transparency

- Meshes received (electroformed Ni meshes available for a very wide range of transparencies)
- Price ~ 330€/mesh
- coated on both sides with $^{10}B_4C$
- done at Linköping Univ.

Tests at CEA – simplified reference geometry
Benchmark for simulations

B$_4$C coated Al plaque at CEA





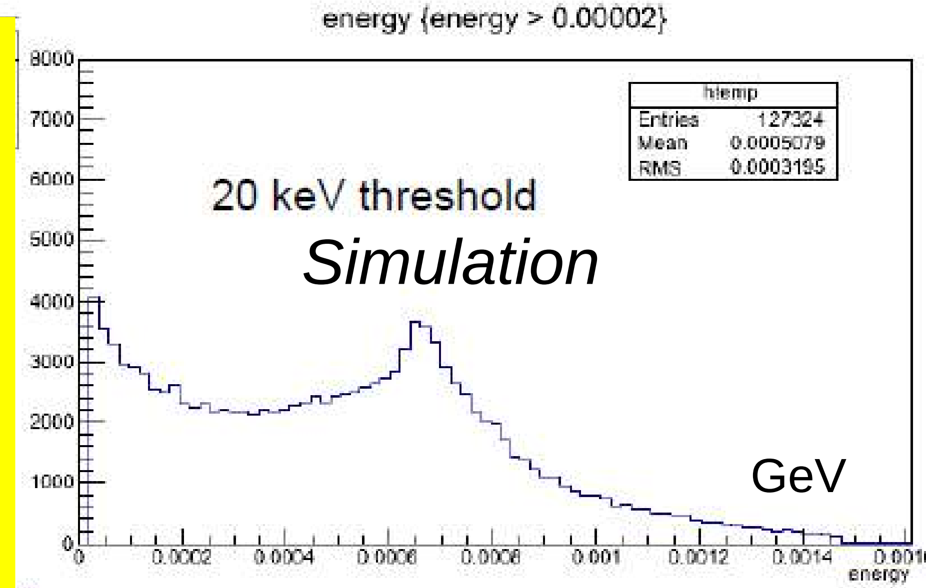
Ne-C$_2$H$_6$ (90-10%)

- ***Anode Voltage: +480V***
- ***Mesh Voltage: +200V***
- ***Drift (B$_4$C plate) Voltage: at ground***

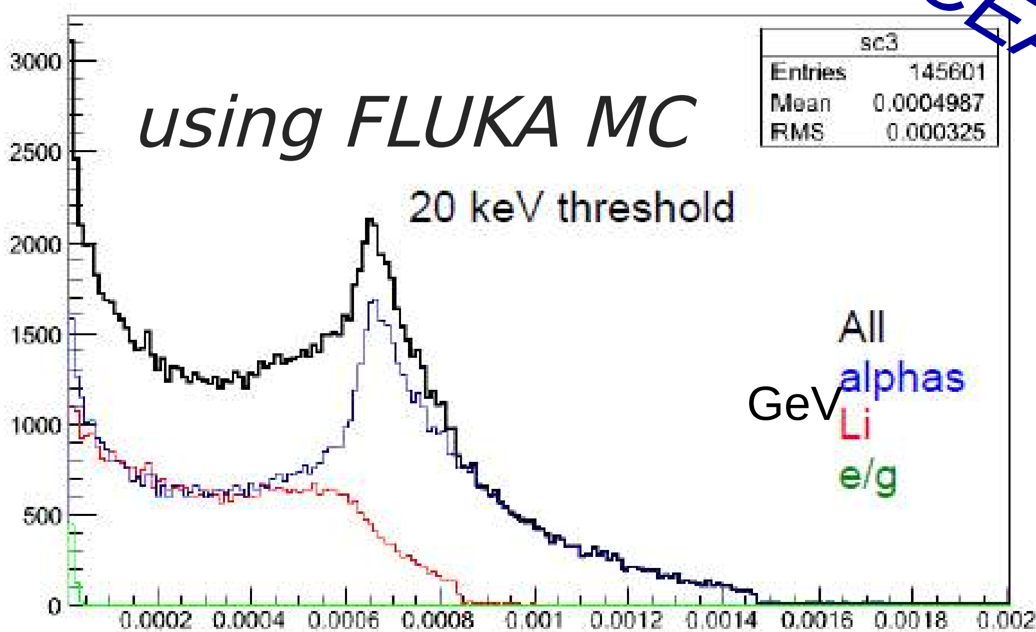
- ***Seal mode operation > 2months! (No gas circulation...)***

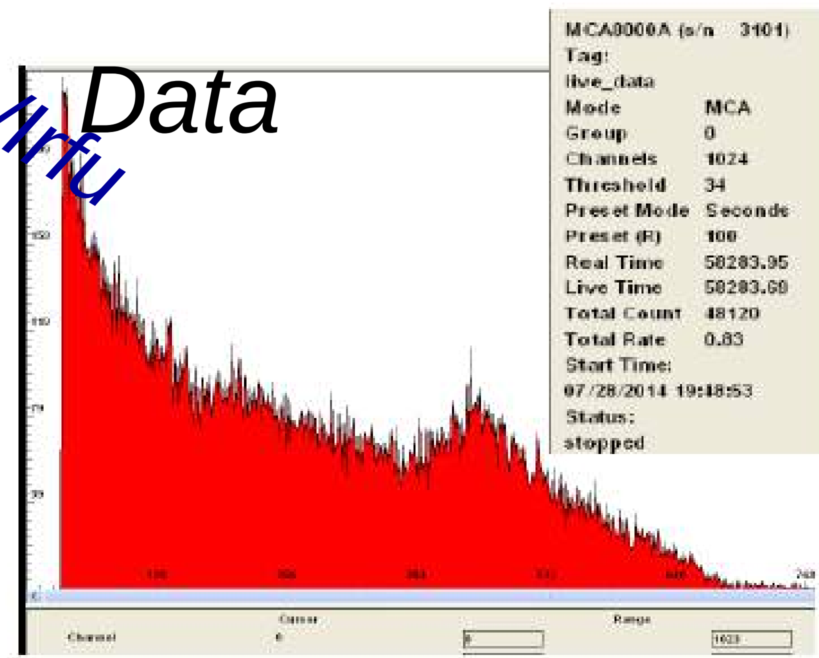
Simulation vs Data

- With the calibrated window (1in.x1in.) made of Boron, the efficiency of micromegas compared to He3 tube is : ***5.05%*** (AmBe source).
- With micromegas directly in a neutron generator, the efficiency of micromegas compared to He3 tube is : ***4.3% (At Schumberger lab)***.
- Good agreement with simulations

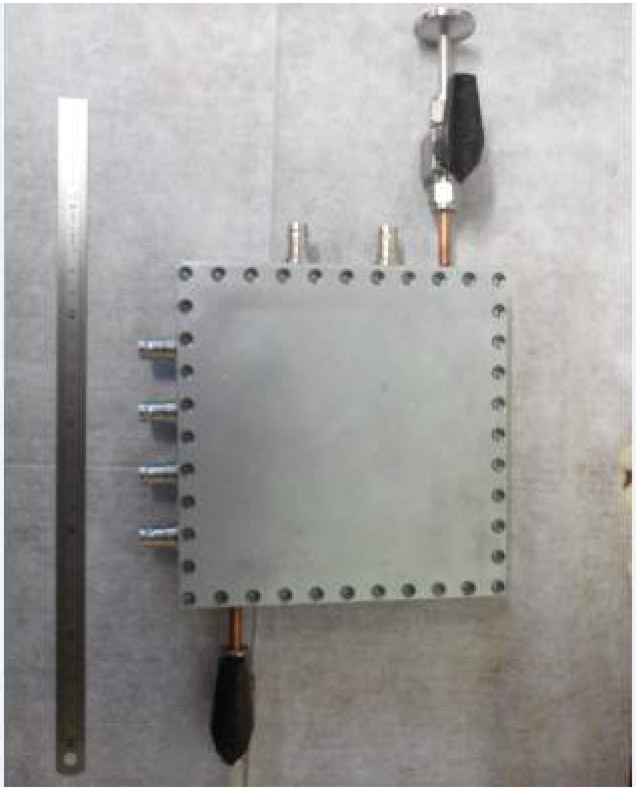
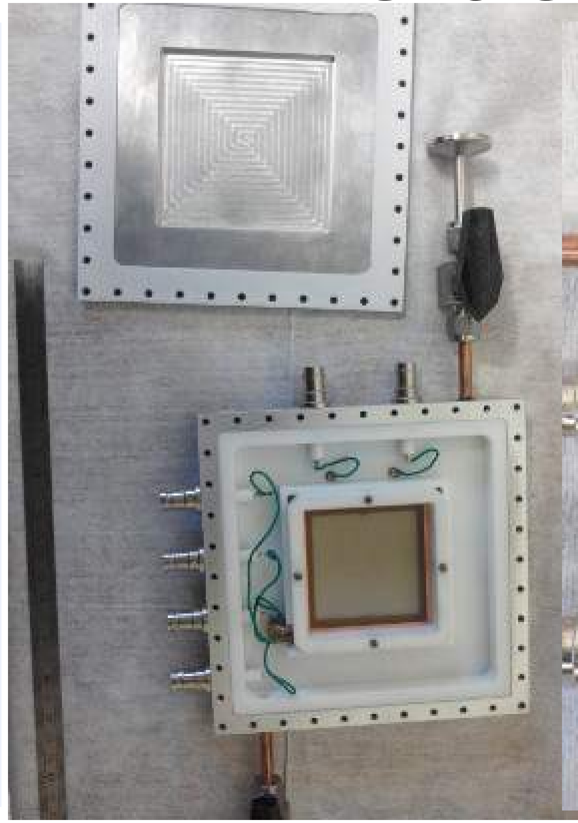
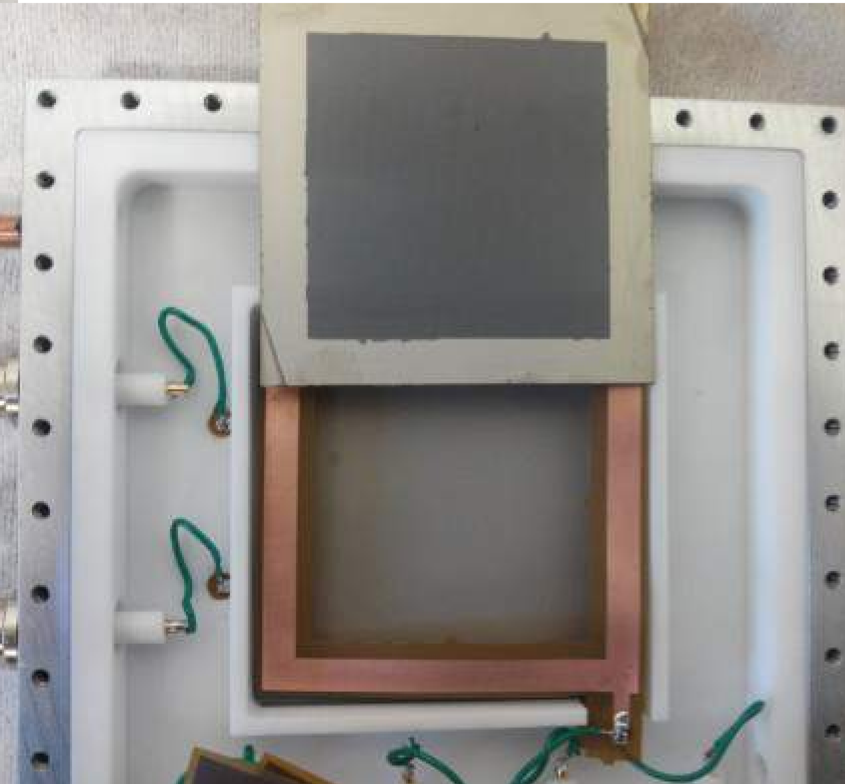
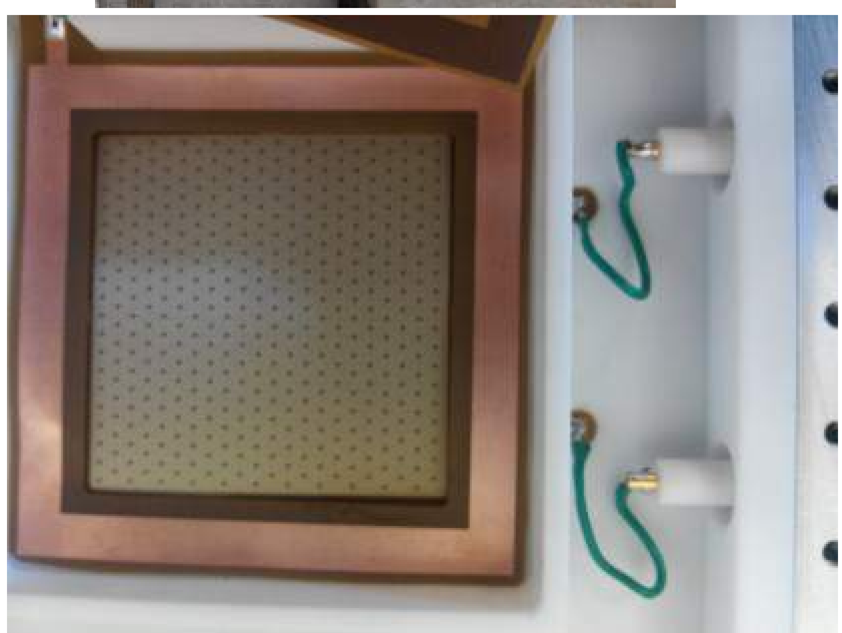


At CEA/Irfu

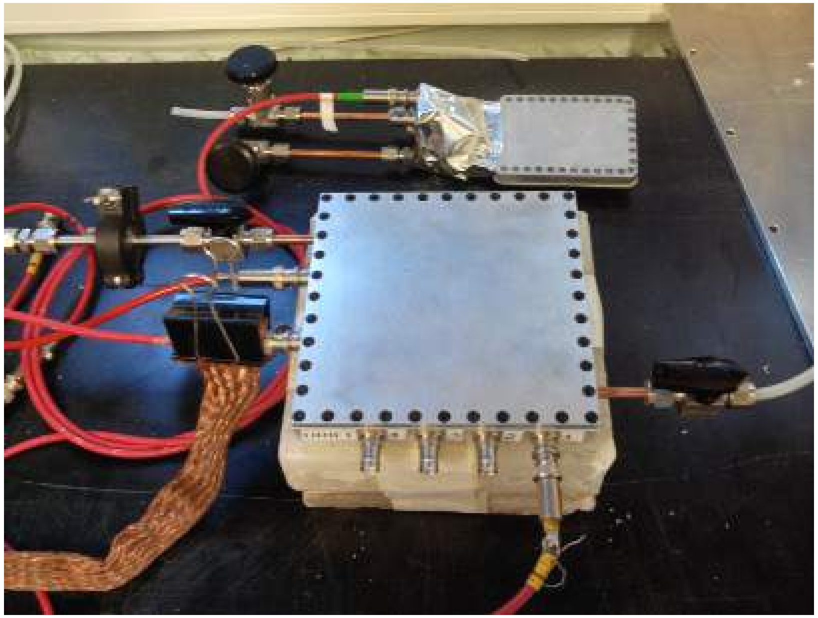


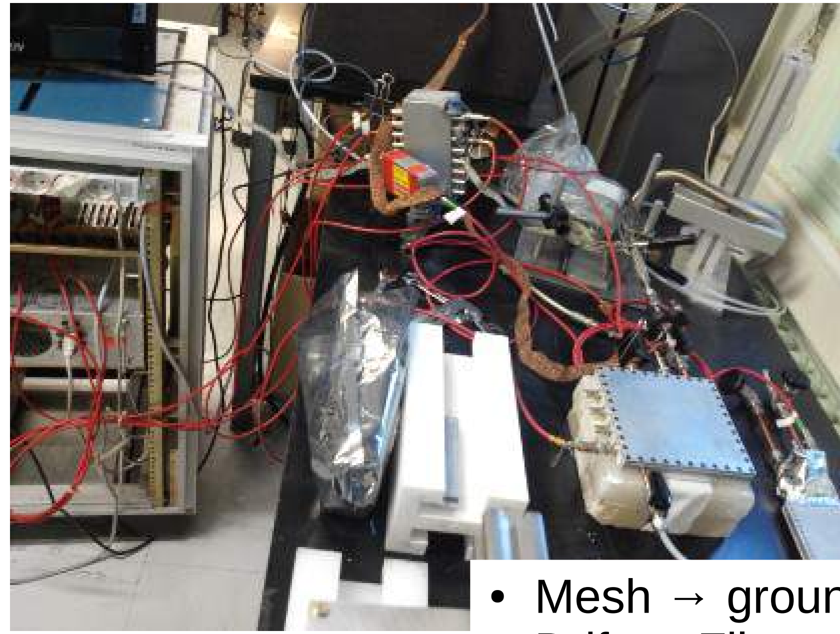


NMI3 detector

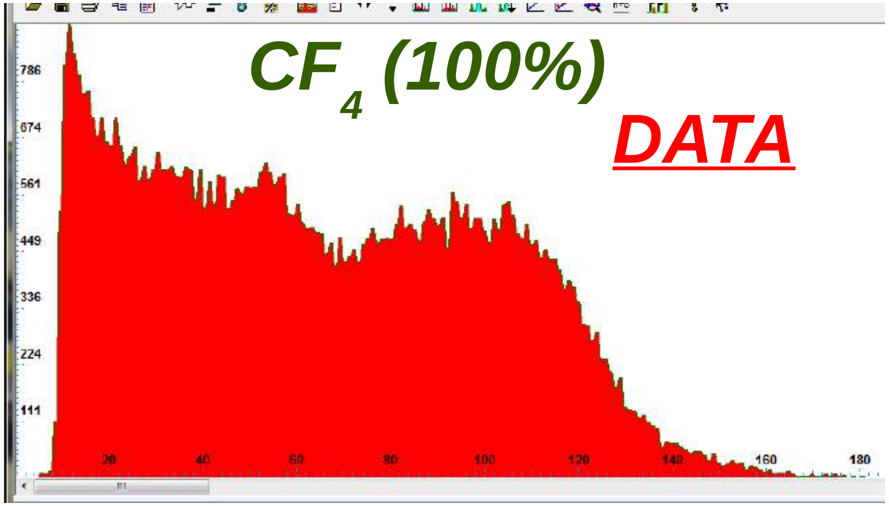
NMI3 – Set up at CEA/Irfu



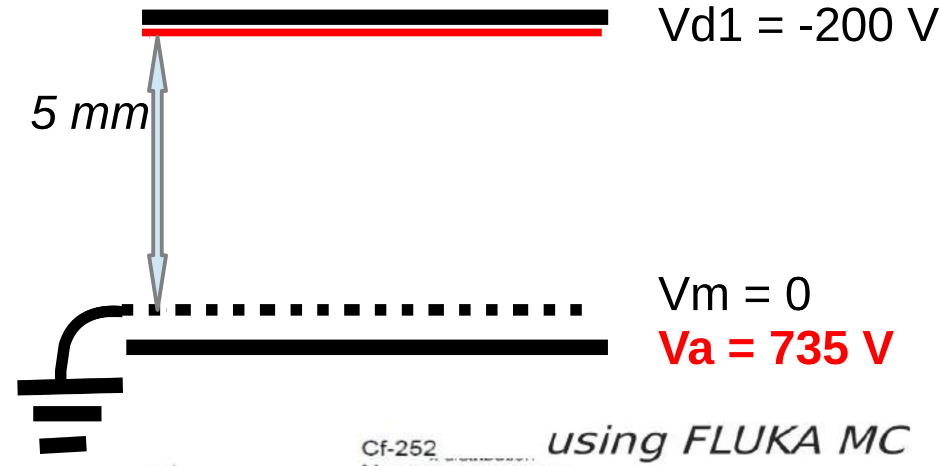


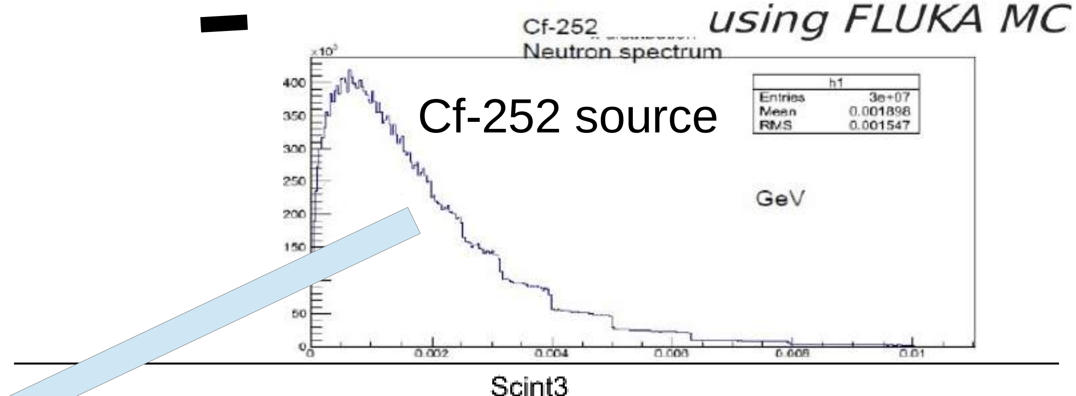
- Mesh → ground
- Drift → Filter → CAEN
- Anode → PA → CAEN
- PA → ORTECRA → OSCI+PC

NMI3 – Simulation vs Data

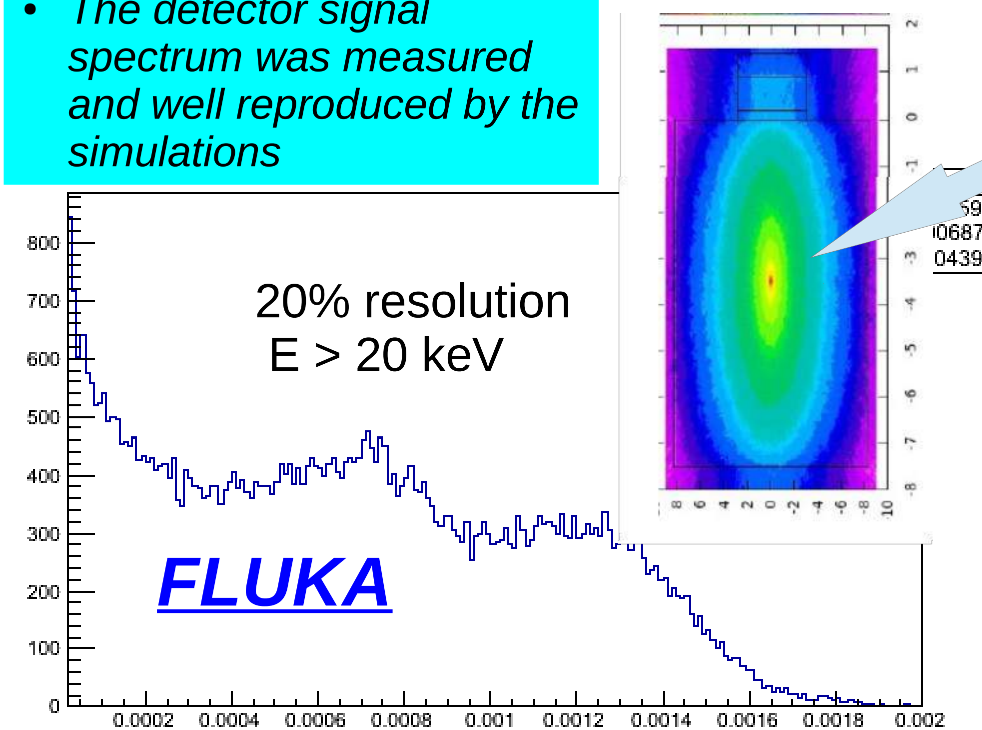


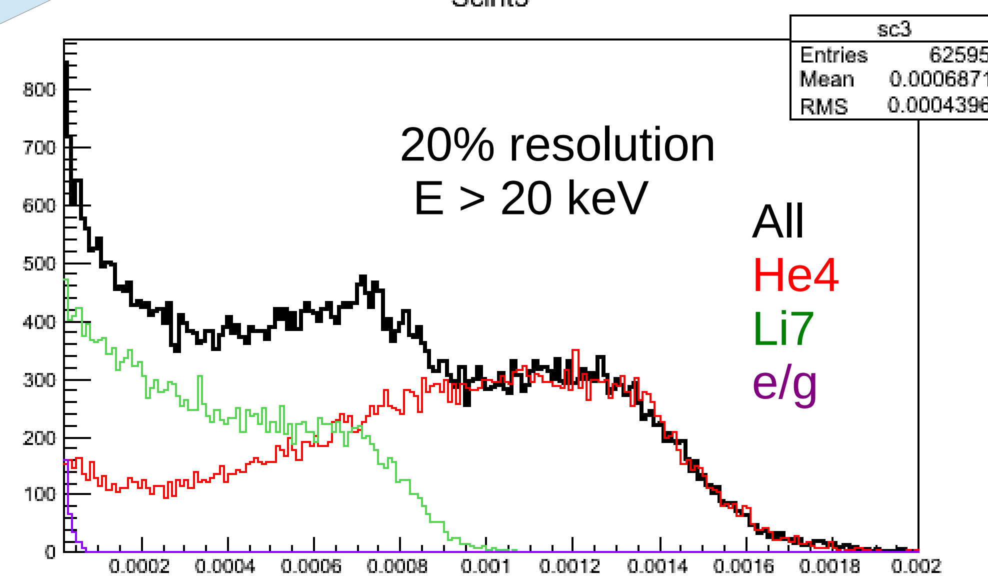
Total Rate ~ 13.16 Hz





- *The detector signal spectrum was measured and well reproduced by the simulations*

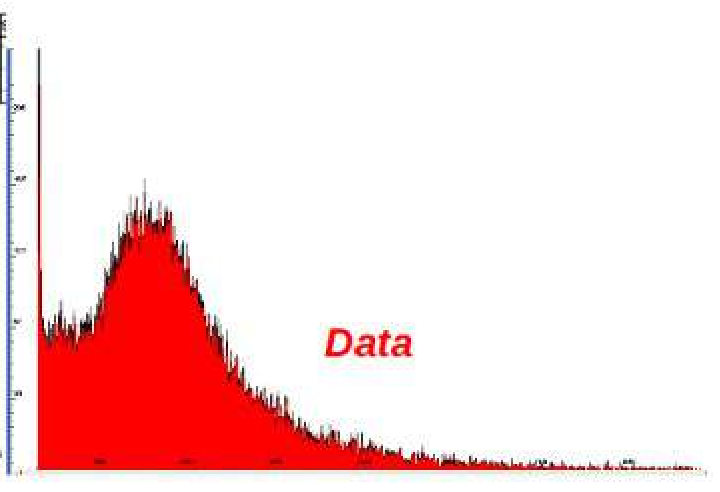


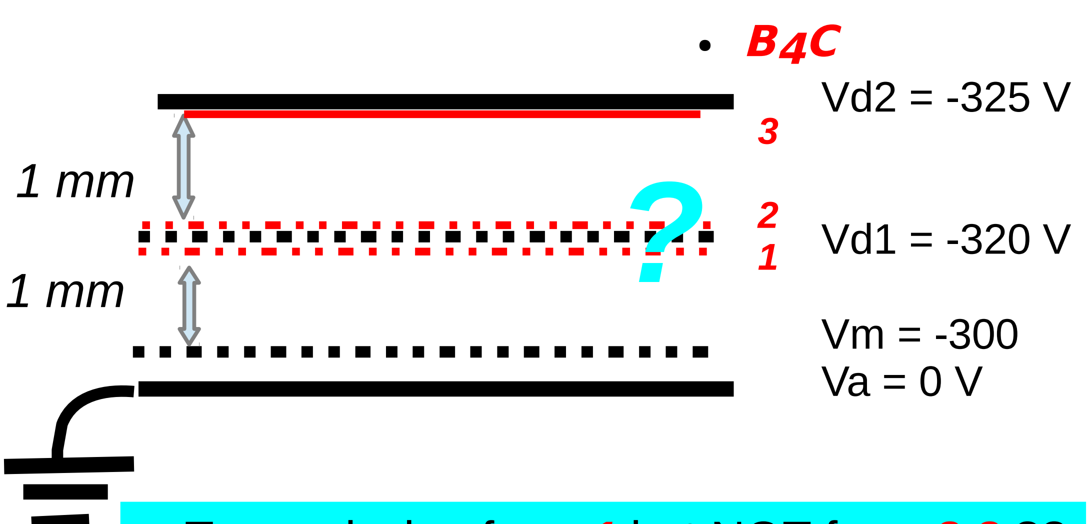


NMI3 – feasibility of the multi-layer structure

- *The detector concept relies on the feasibility of $^{10}B_4C$ deposition on different types of thin meshes (Nickel, stainless steel, or copper cladded Kapton foils) leading to an efficient neutron conversion and on the transport of the charges through the multi-layered structure onto the micromegas amplification stage .*
- *A campaign of $^{10}B_4C$ sputtering depositions was done at Linköping, where* ***5 µm thick****, 10 and 20 % optical transparent* ***Nickel meshes*** *are covered on both sides with a* ***1.5 µm*** thick ***$^{10}B_4C$ layer****.*
- *One of these meshes was assembled in the prototype above a bulk-micromegas amplification stage to perform a series of measurements with a ^{252}Cf neutron source.*

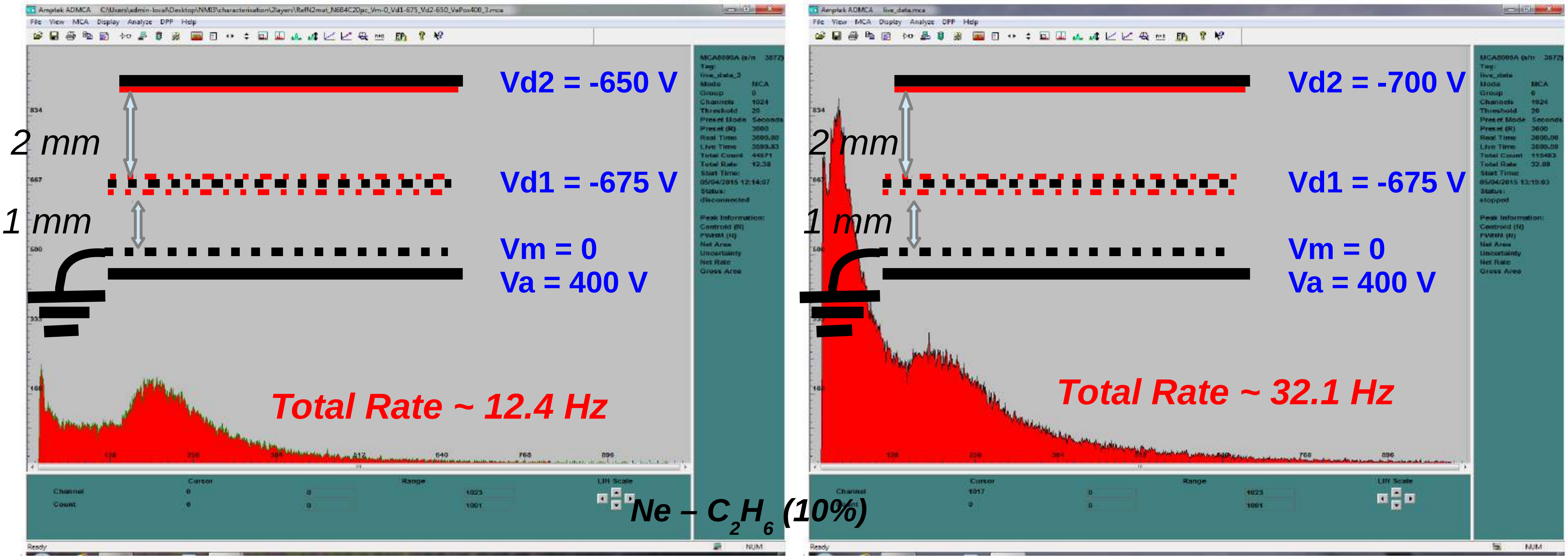
- *The* ***next step*** *was to add a double-coated with $^{10}B_4C$, Ni mesh, and having a single-coated aluminium end plate to measure and quantify the contributions on the counting rate from each of the 3 $^{10}B_4C$ layers.*





- Transmission from ***1*** but NOT from ***2***,***3*** ??

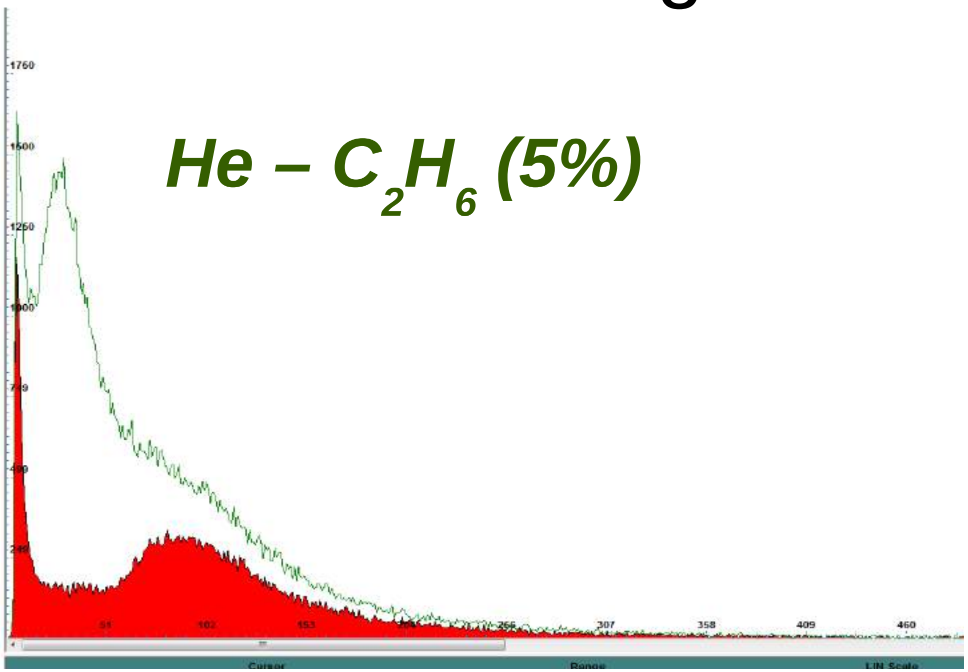
- *Increasing the applied voltages and doubling the thickness of the top layer*

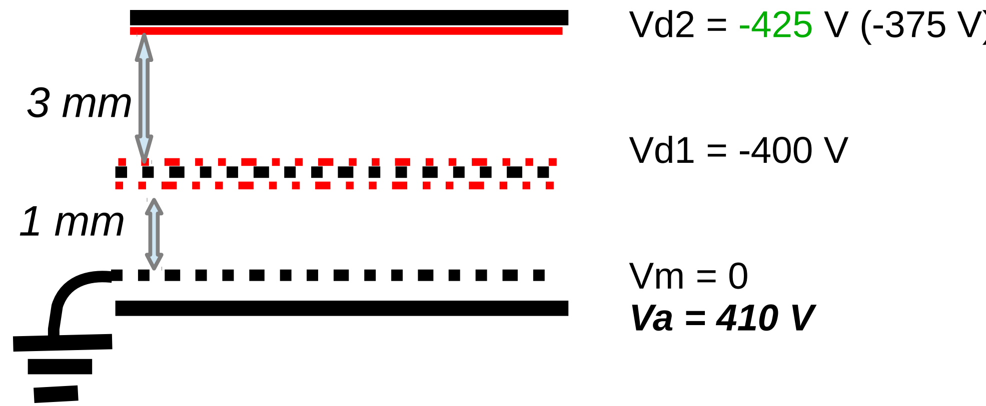


Data measured during 1h with inverted drift voltages to get contribution from the double-coated middle-bottom layer (1 x B_4C layer) (left plot) and from all 3 x B_4C layers without inverting the drift voltages (right plot).

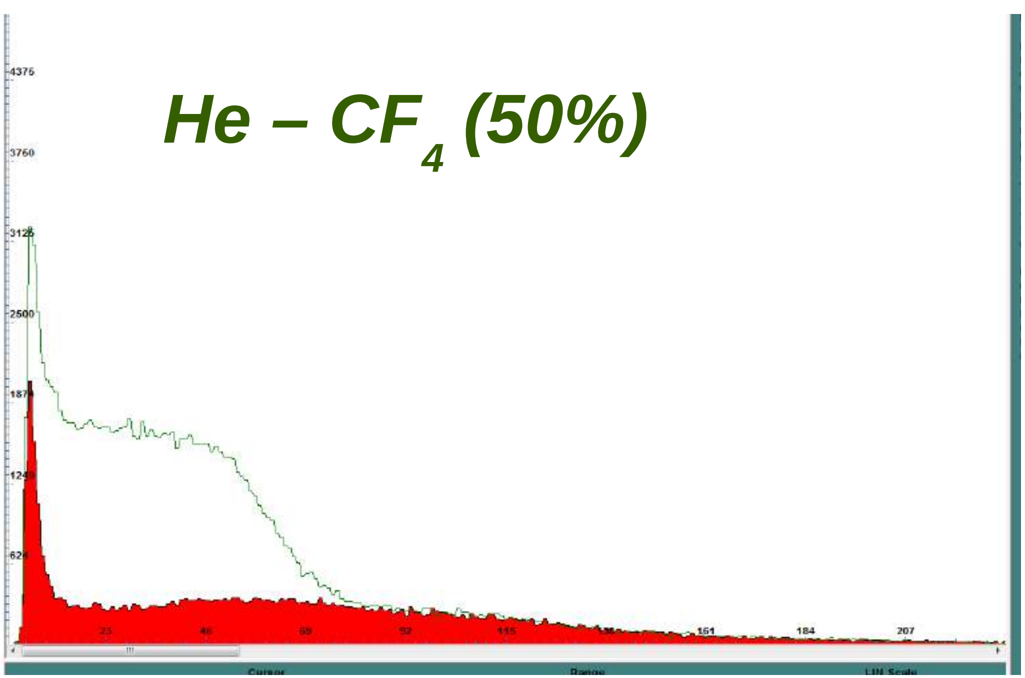
- ***The principle of the multi-layer structure works!***
- *Measured total rate agrees, BUT #electrons not…*
- *The ratio of the fields taking into account the distance of 2 mm between the two drift regions is extremely high ~**25** compared to F = 5 that was used in the electric field simulations, proving that **the transparency through the nickel mesh is very small.***

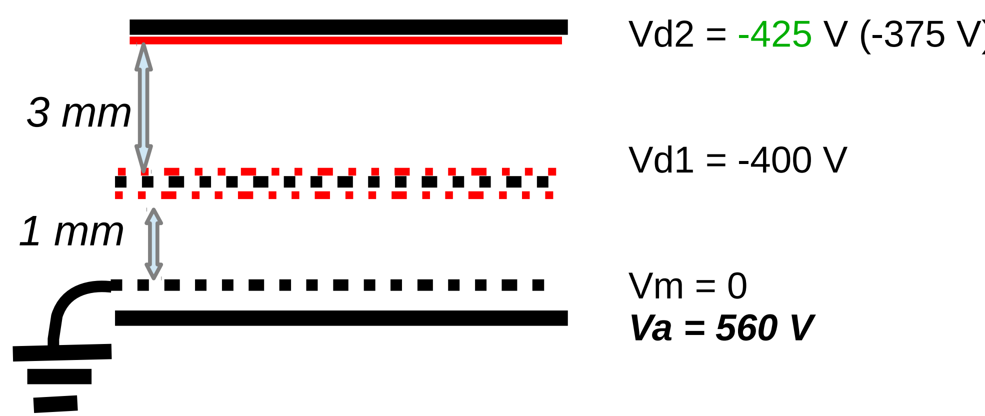
Testing different gas mixtures





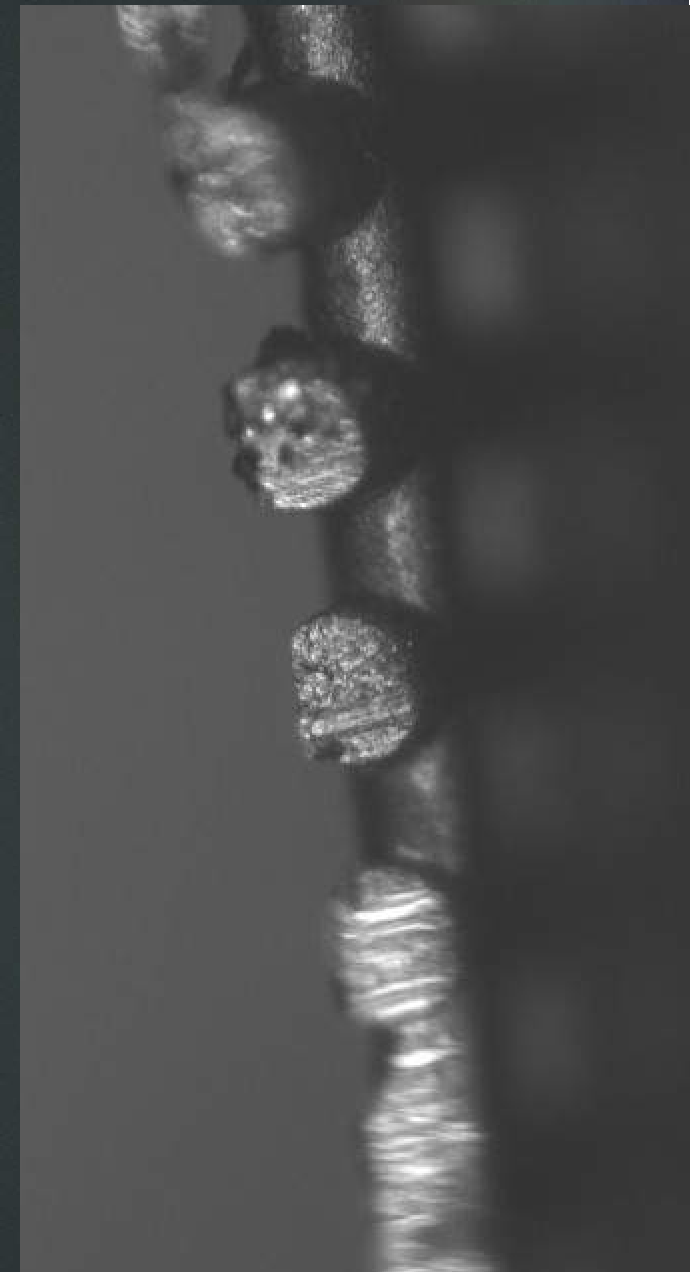
R=37.69 Hz, 14.61 Hz



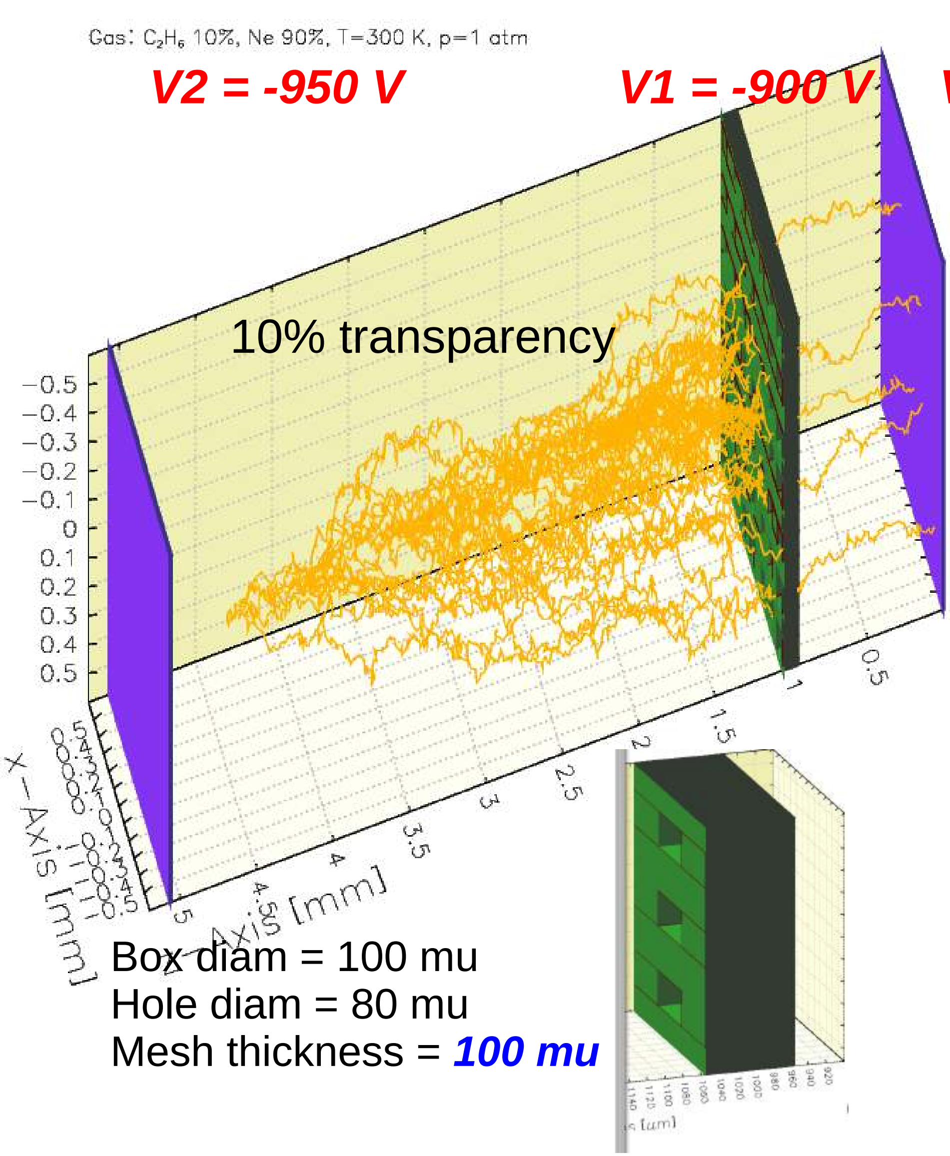


R=31.10 Hz, 11.90 Hz

- *A more careful study of the nickel mesh (~20% transparency) with a microscope revealed that its thickness is ~* ***130 µm*** *compared to ~* ***4-5 µm*** *that we have requested from the manufacturing company.*
- *This was something very unfortunate limiting by far the flexibility/performance of our detector.*
- *New nickel meshes* ***5 µm*** *thick are ordered and expected to be delivered very soon.*

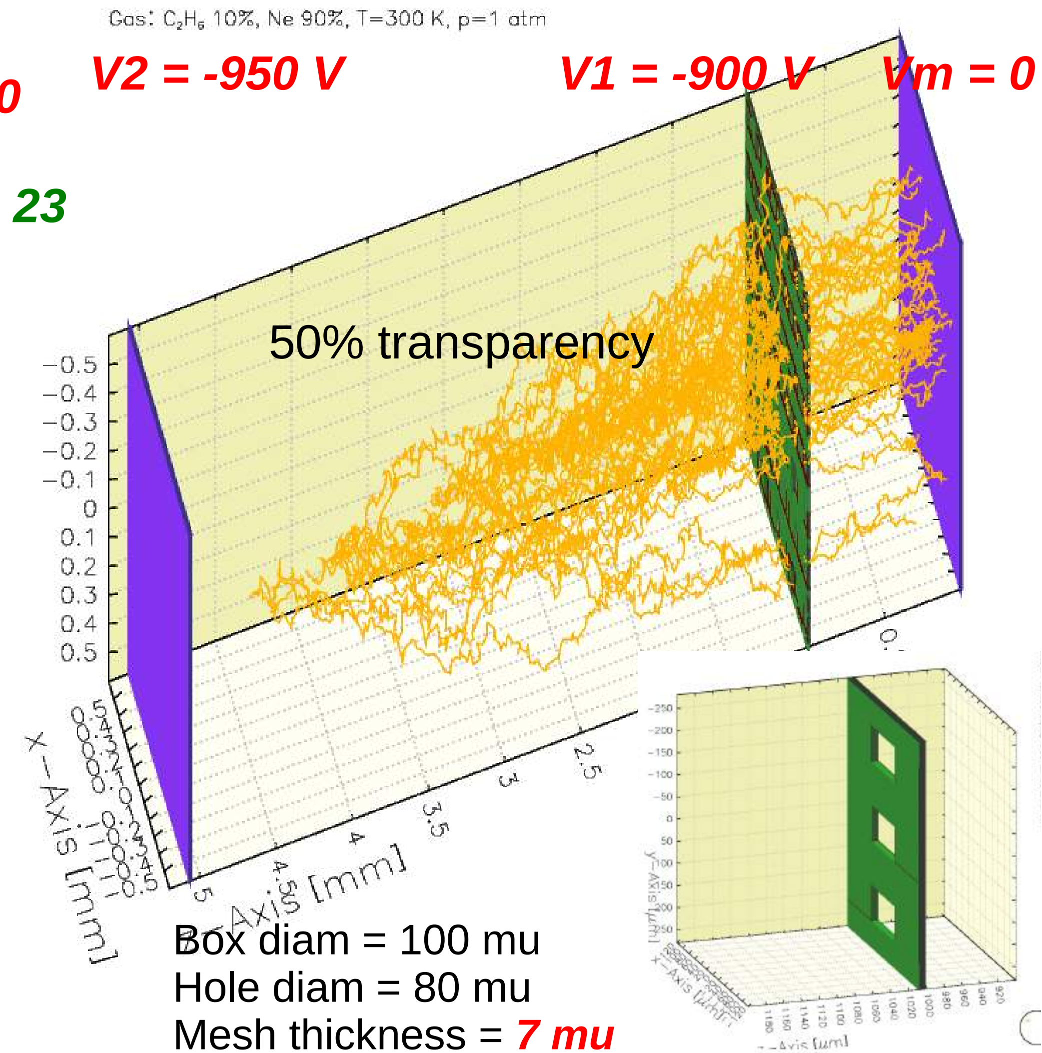


Simulation / box model (garfield-nebem)



Box diam = 100 mu
Hole diam = 80 mu
Mesh thickness = ***100 mu***

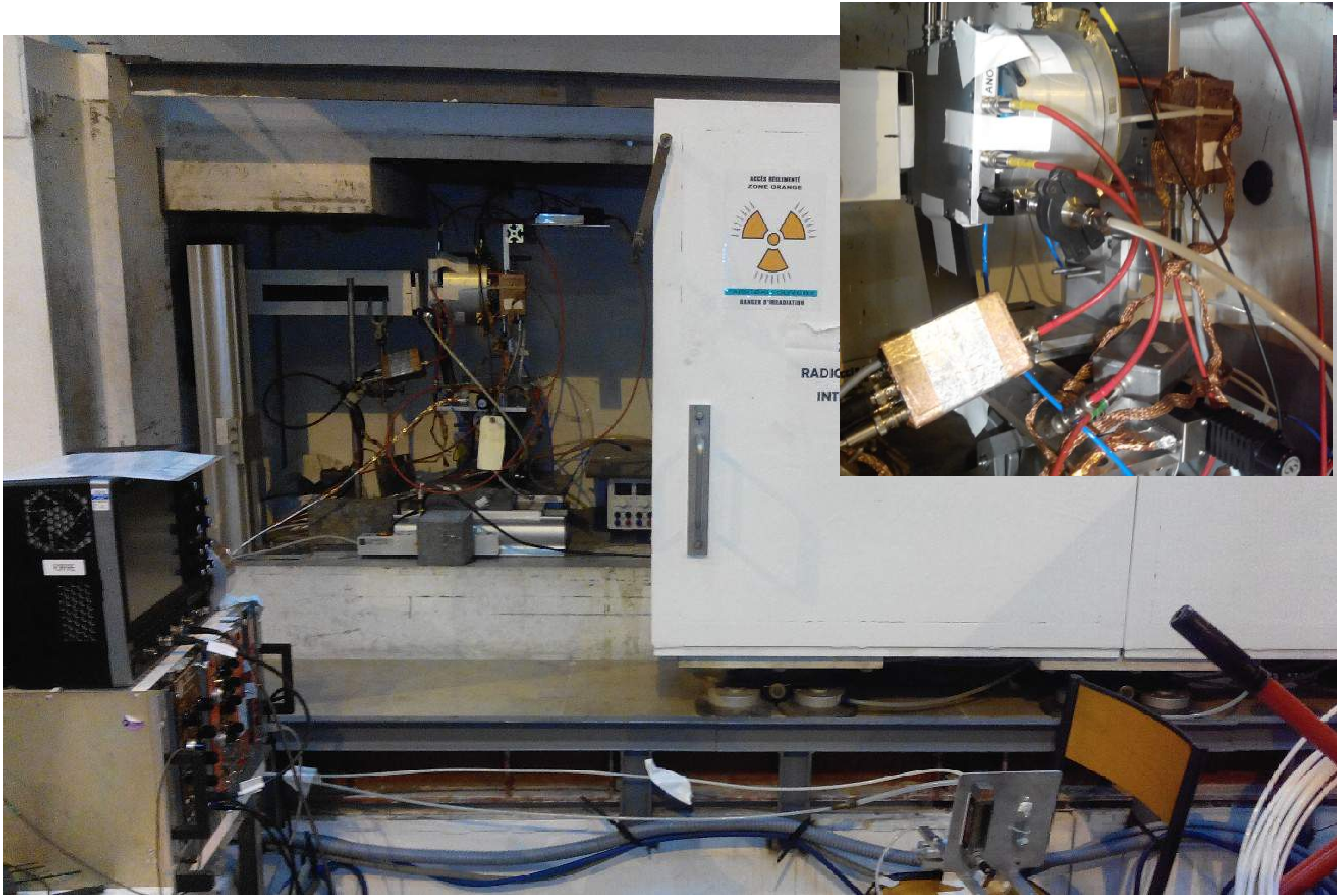
f = 23



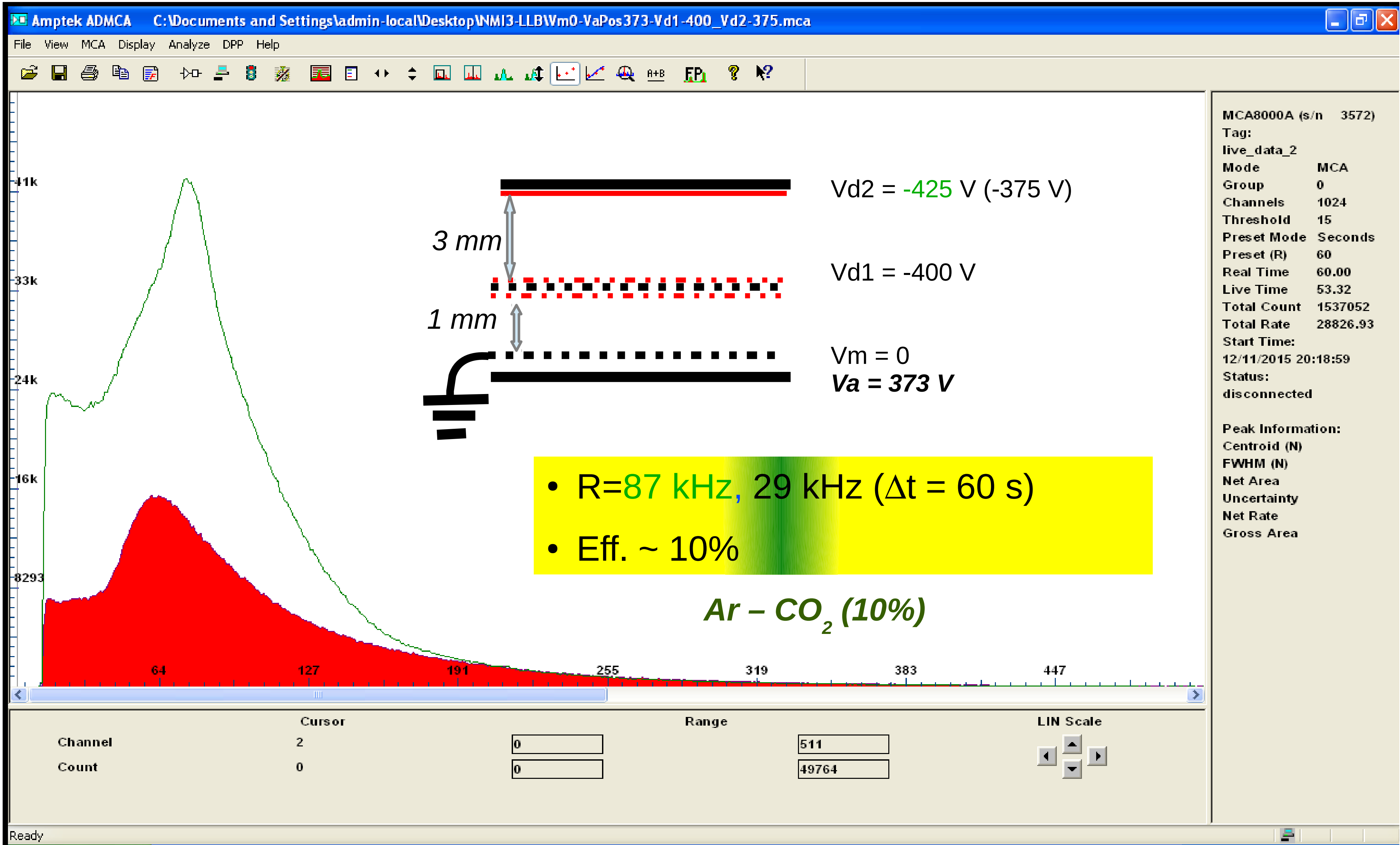
Box diam = 100 mu
Hole diam = 80 mu
Mesh thickness = ***7 mu***

- we are waiting for coating of the ***5μm*** meshes to continue on ***bulk***
- Waiting for that, we performed measurements at with a neutron beam at the ***Orphée*** reactor (December 2015)

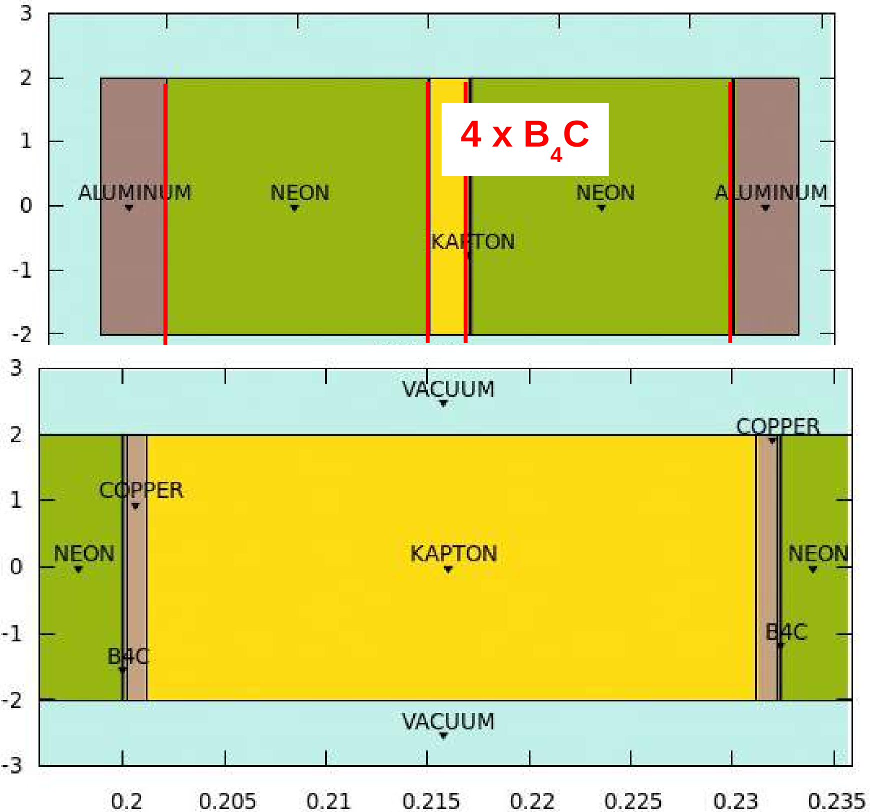
Set-up at the Orphée reactor



Measurements with a neutron beam at the Orphée reactor



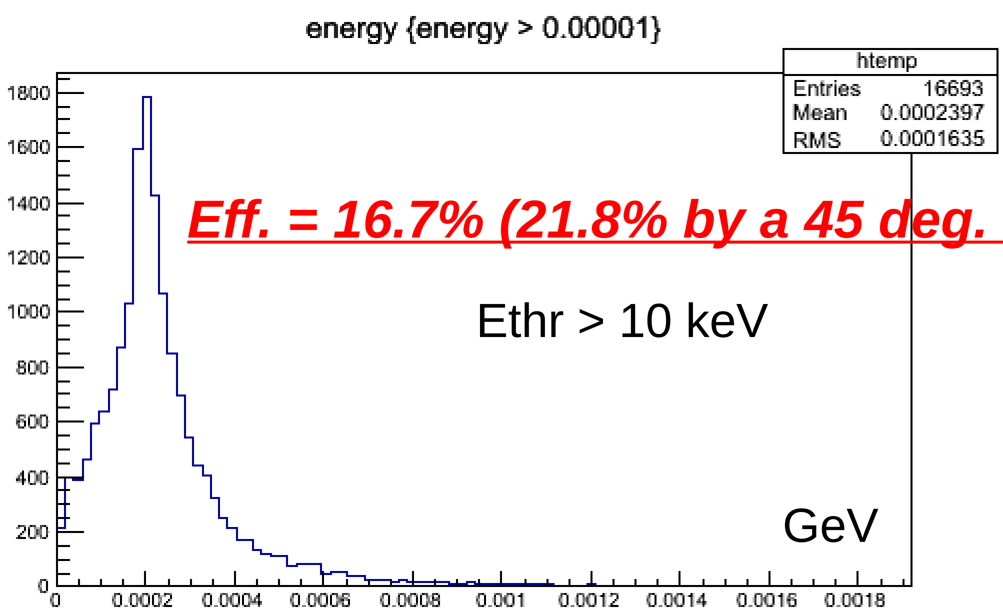
Towards *SINE2020*: Implementing the microbulk technology



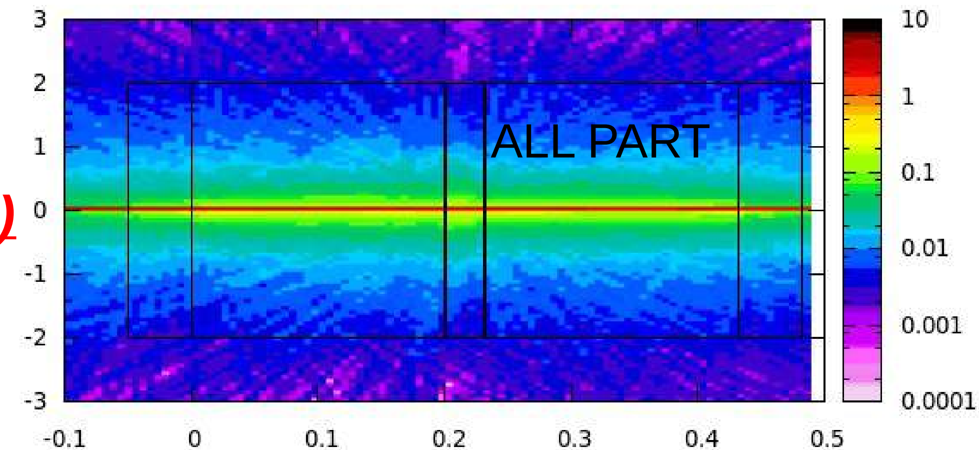
- ***2 gas layers***
- ***4 x B_4C layers (2μm)***

using FLUKA MC

- 2 Al end plates 4 x 4 cm: 0.5 mm
- 2 Gas layer Neon: 2 mm
- 4 layers of converter B_4C: 2 μm
- 1 Kapton layer: 300 μm
- 2 Copper layers: 10 μm

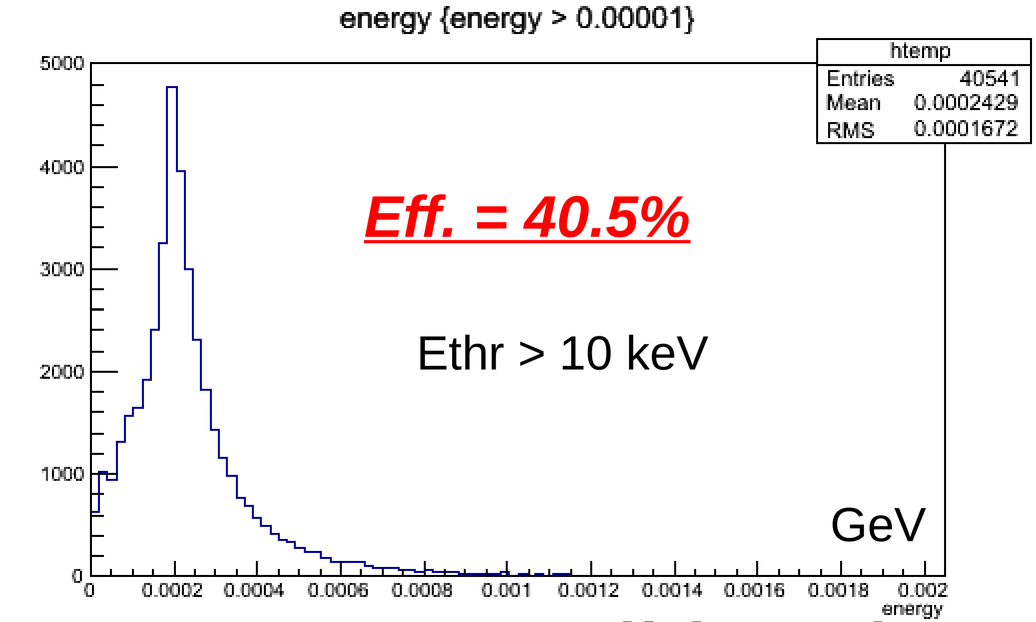


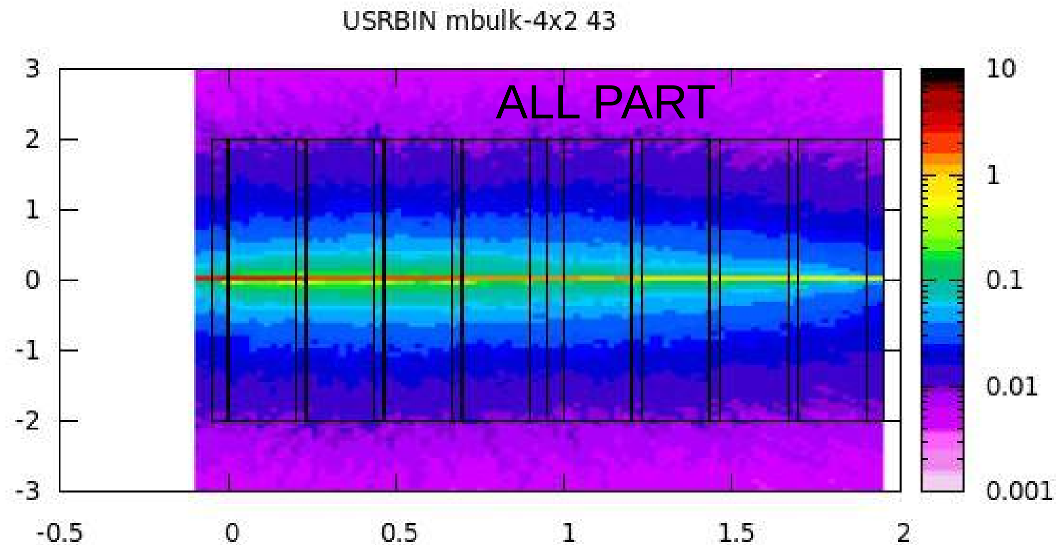
Eff. = 16.7% (21.8% by a 45 deg. tilt)



2 x 4 detectors units

- **8 gas layers**
- **16 x B_4C layers (2μm)**

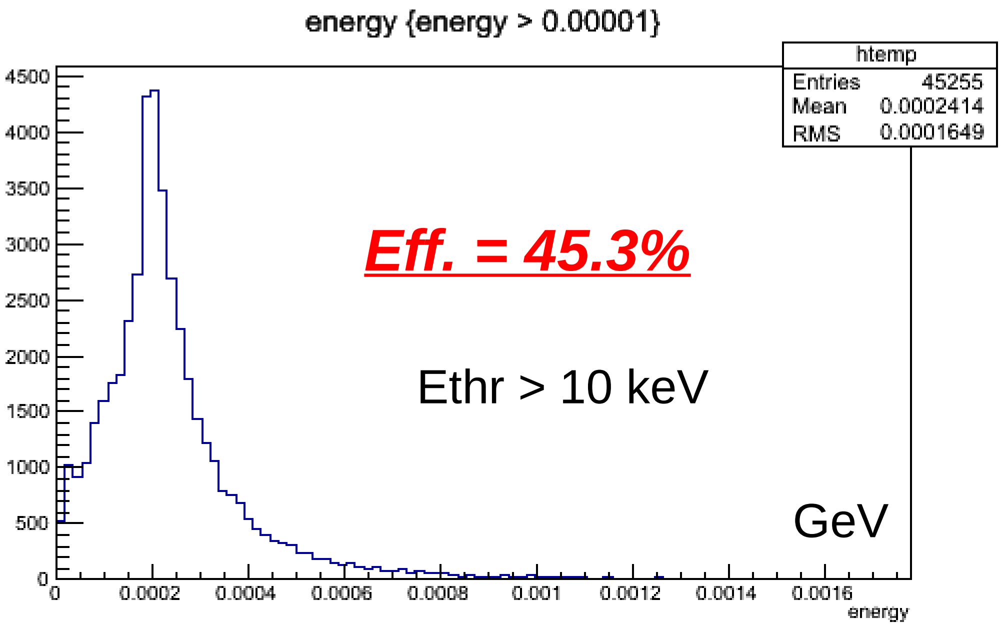


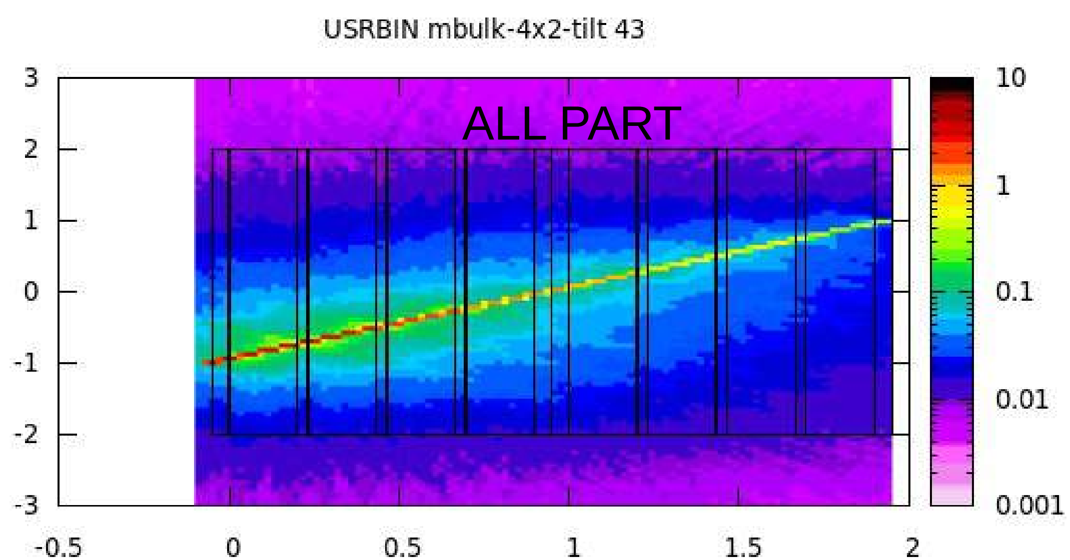


using FLUKA MC

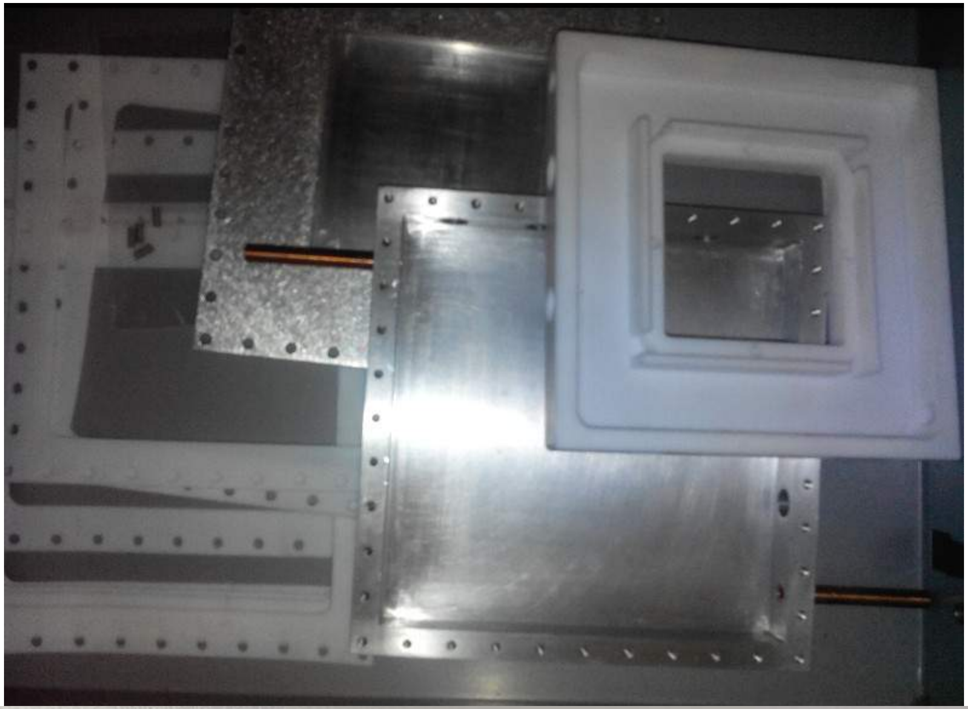
Tilting the detector

Direction cosine of beam with y-axis: 0.707 => 45 deg.

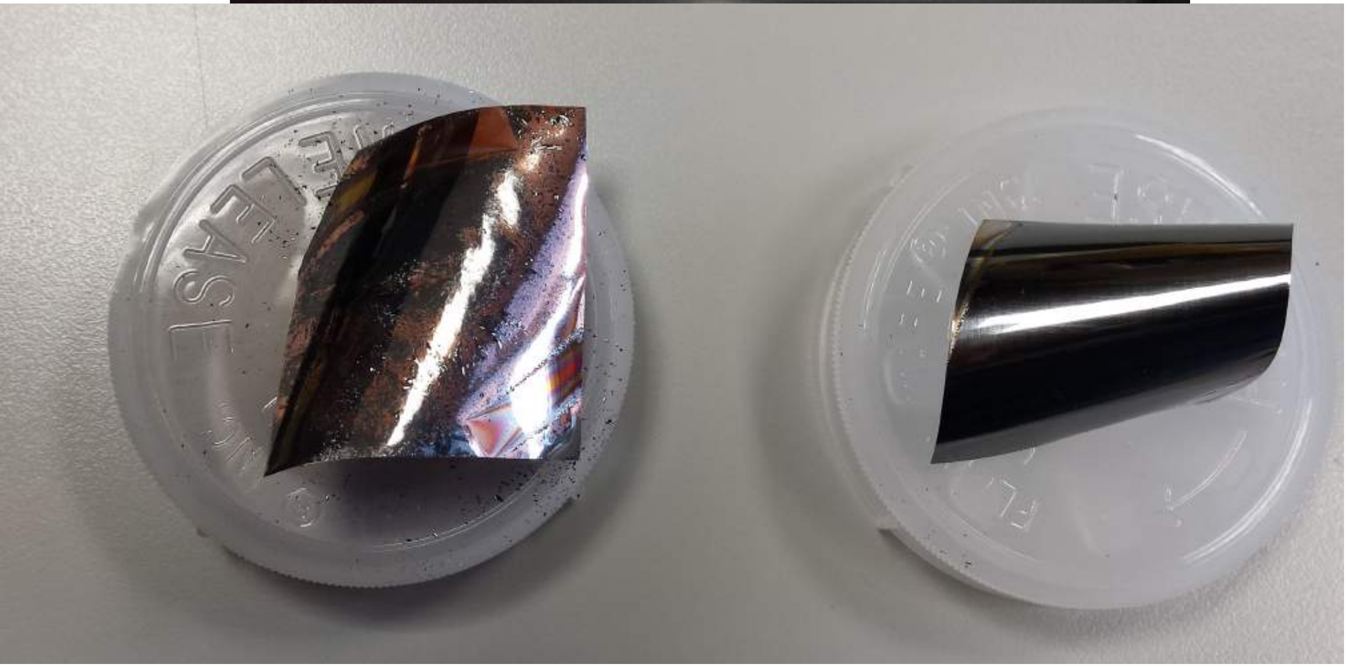




Multi-Microbulk Detector



- We have done some tests trying to deposit B_4C on Microbulk raw material.
- The deposition on the copper doesn't work, but on the Nickel coated copper it looks great, even after 2 months from the time the deposition was done.
- So, Nickel coated Microbulks seems it is the good way to proceed.



- Easy to make a mosaic
- No transmission problems
- Better spatial resolution
- More electronics
- Evaluation of the cost

Summary & Future plans

- ***Irfu/LLB*** → Innovative concept for a cost-effective, high-efficiency, large scale neutron detector: a compact stack of multi-stages ^{10}B covered meshes with a micromegas gaseous amplification.
- ***Simulations***: By placing two double 2-mesh or 3-mesh detector units, the neutron efficiency is 49% and 57% respectively. With a 45° tilt of the full detector with respect to the neutron beam, efficiencies are as high as 57% (2-mesh structure, 20 $^{10}B_4C$ layers) and 64% (3-mesh structure, 28 $^{10}B_4C$ layers).
- A ***prototype*** was designed and built: a modular 15x15x2 cm^3 gas chamber in which up to 4 meshes can be stacked above a micromegas amplification structure, either a standard bulk-micromegas or a Kapton micro-bulk micromegas.

- ***The principle of the multi-layer structure works!***
- *Measured total rate agrees, BUT #electrons not...*
- *Due to the wrongly big thickness of the Ni meshes (**130 µm** instead of **5 µm**), the electron transmission was limited*
- *We are waiting for coating of the **5µm** meshes to continue on **bulk***
- Waiting for that, we did start to work on ***microbulk***

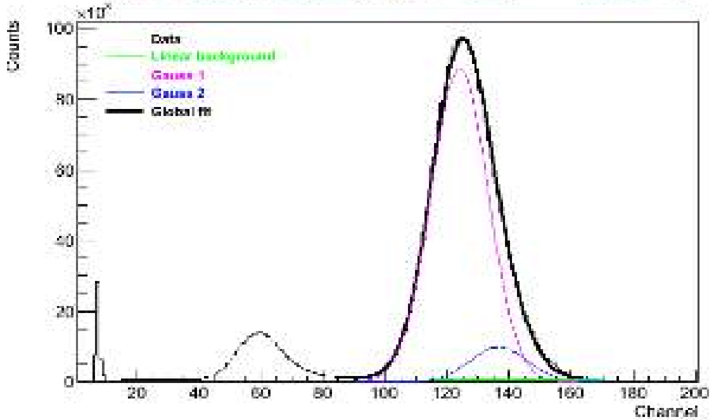
SINE2020

- ***Micro-bulk micromegas*** → Innovative concept for a cost-effective, high-efficiency, large scale neutron detector: a mosaic of micro-bulk micromegas coated with $^{10}B_4C$.
- ***Simulations***: By placing eight micro-bulk micromegas detector units, the neutron efficiency is 40% and with a 45° tilt of the full detector with respect to the neutron beam, efficiencies are as high as 45% (16 $^{10}B_4C$ layers 2 µm thick.).
- A ***prototype*** was designed and built: a modular 15x15x2 cm^3 chamber in which up to 4 kapton micro-bulk micromegas can be stacked
- ***Tests to deposit B_4C*** on Micro-bulk raw material are on going showing that the Nickel coated Copper Micro-bulk is the good way to proceed
- Start testing the prototype + funding a post-doc...

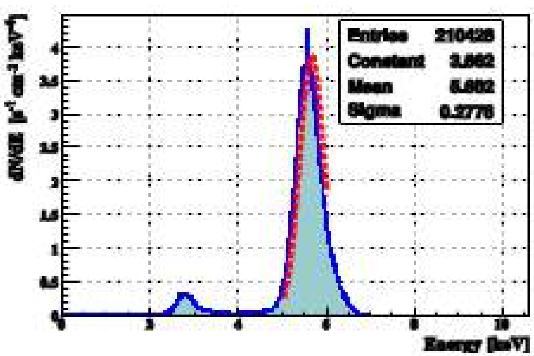
Back-up slides

Energy and spatial resolution & stability

<u>Bulk</u>: 55Fe Calibration with Ar – 5% isobutane
@ 1 bar **FWHM @ 6 keV = 17.6 %**

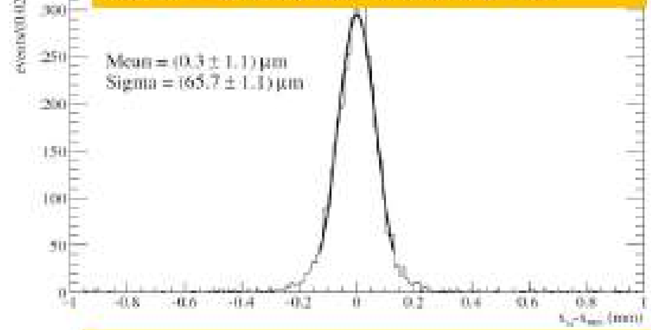


<u>Microbulk</u>: 55Fe Calibration with Ar – 5% isobutane
@ 1 bar **FWHM @ 6 keV = 11.5 %**

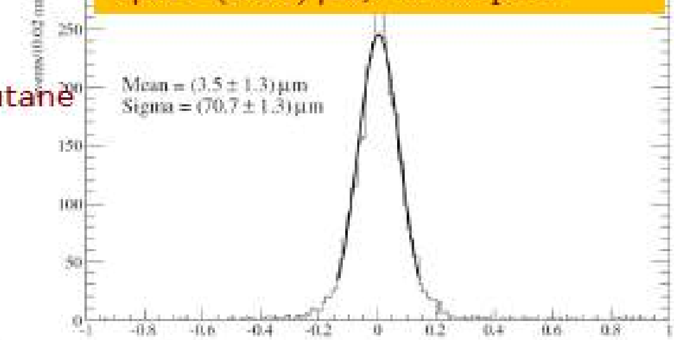


Bulk: Spatial resolution measurements for the MAMA project (sLHC)

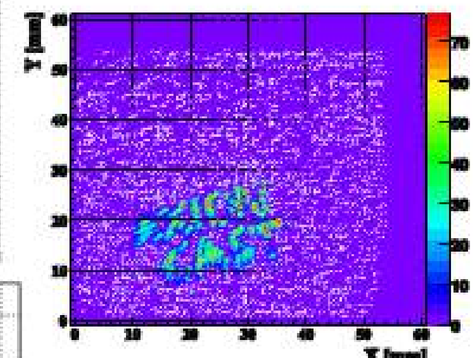
σμM = (24±7) μm .25 mm pitch

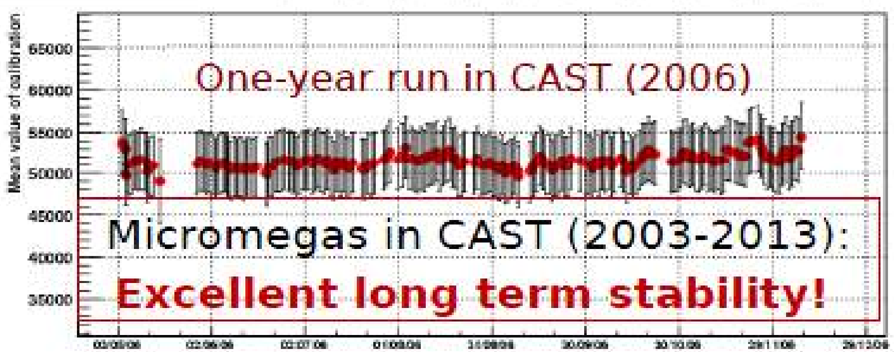


σμM = (36±5) μm, .5 mm pitch



Microbulk: Image taken using a collimator with the words "axion cast"





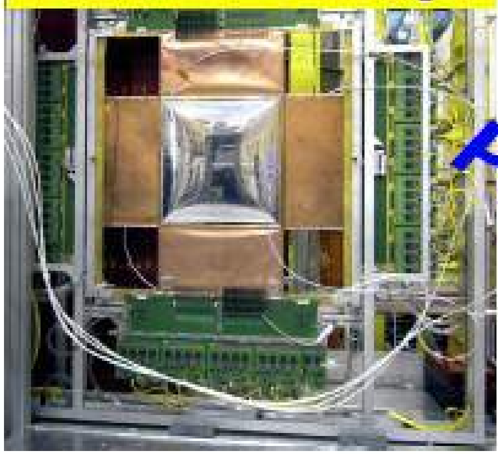
One-year run in CAST (2006)

Micromegas in CAST (2003-2013):
Excellent long term stability!

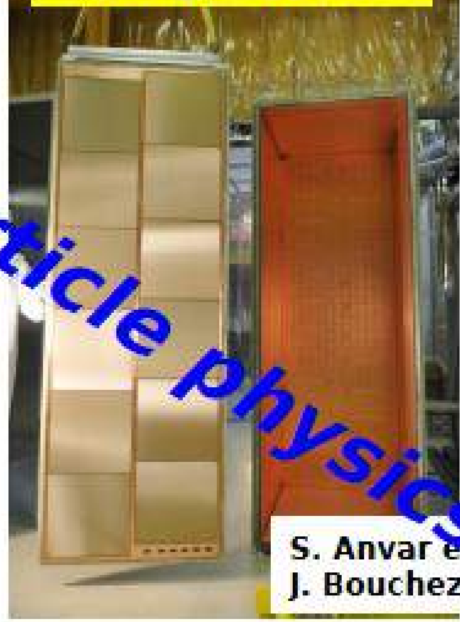
280 x 210 mm

Micromegas applications

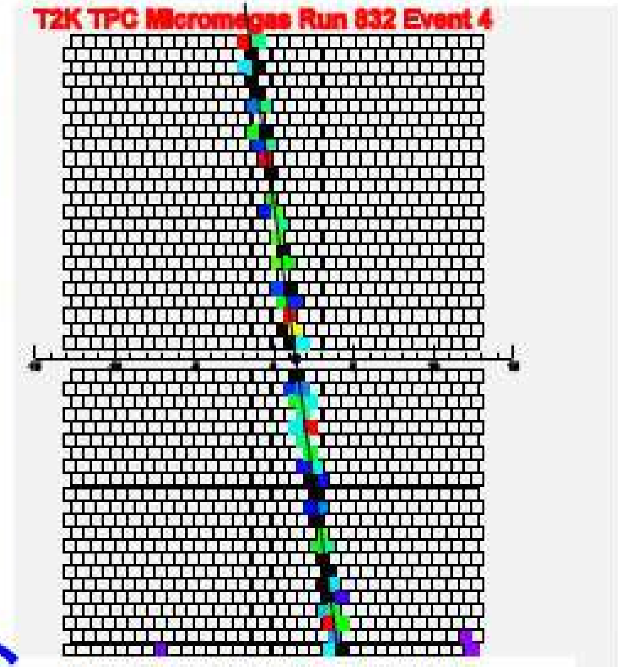
COMPASS
40x40 cm2 Micromegas



T2K
Large area



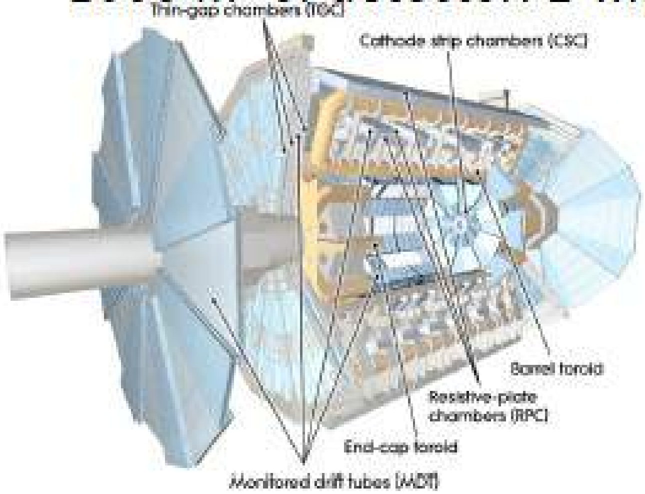
Particle physics

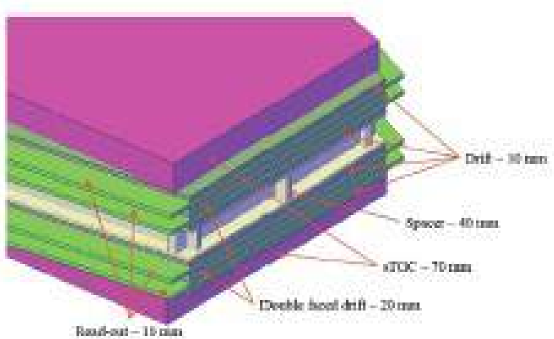


S. Anvar et al. NIM A602:415-420, 2009
J. Bouchez et al. NIM A574:425-432,2007

ATLAS @ sLHC: large + ***reliable*** detectors

1000 m^2 of detector: 2 wheels of 125 m^2 quadruplets





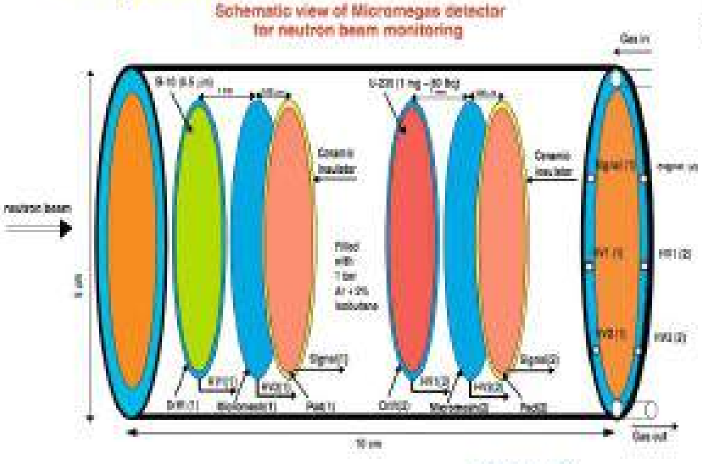
Micromegas applications

n_TOF

Low mass online neutron flux monitor:

- ➢ Minimize beam perturbation and induced background
- ➢ Cover a wide energy range

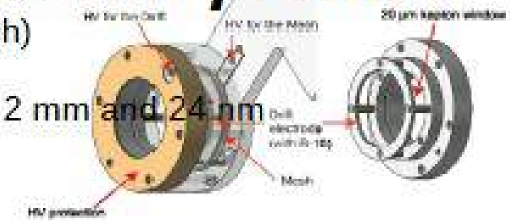
Drift Cathode (1):
25 µm coppered (1 µm) Kapton
+ 1.5 µm of **B-10**
Drift Cathode (2) :
1.5 µm aluminised (~ nm) mylar
+ 1 mg **U-235** (99.94%)
Micromesh + Anode strip:
Micro-Bulk (5 µm Cu)
+ 50 µm Kapton (with 70500 holes)
+ 5 µm Cu)

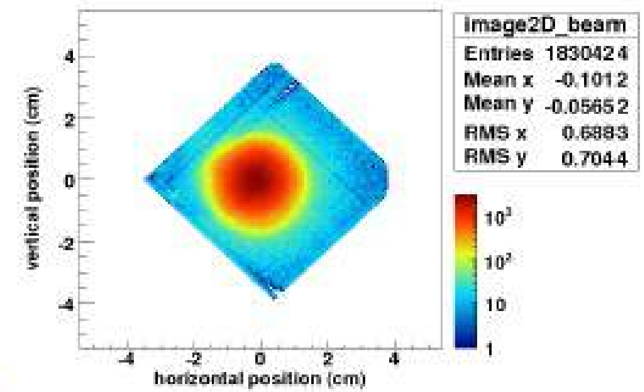


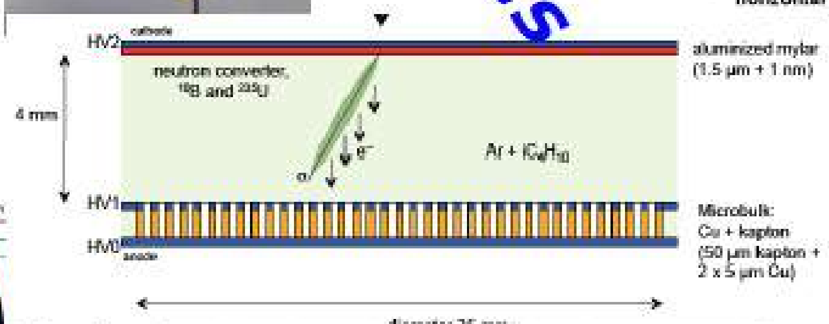
Nuclear physics

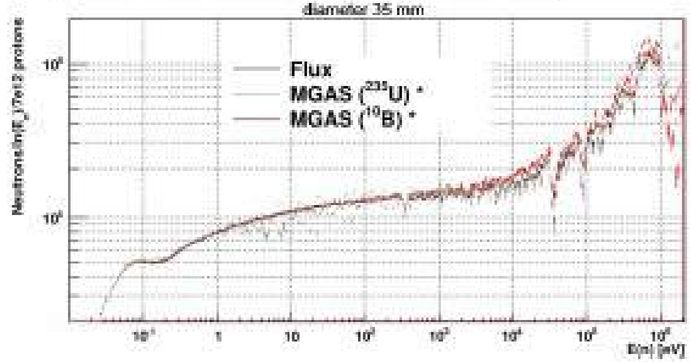
Neutron beam profiler

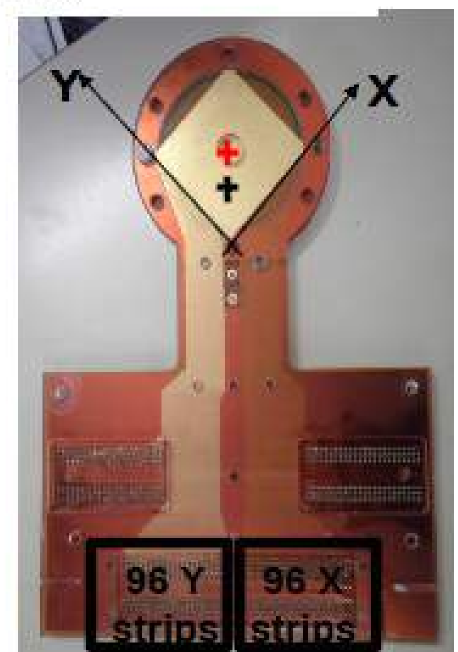
- 6x6 cm2 (2x106 strips, 0.5 mm pitch)
- drift gap = 4 mm
- converter: 10B4C enriched in 10B, 2 mm and 24 nm
- Ar + (10%)CF4 + (2%) iC4H10



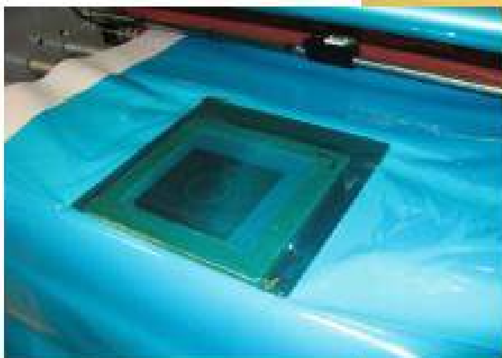


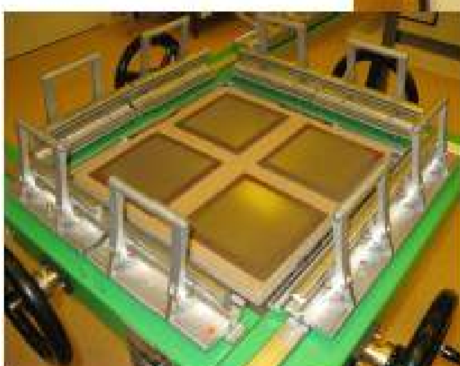


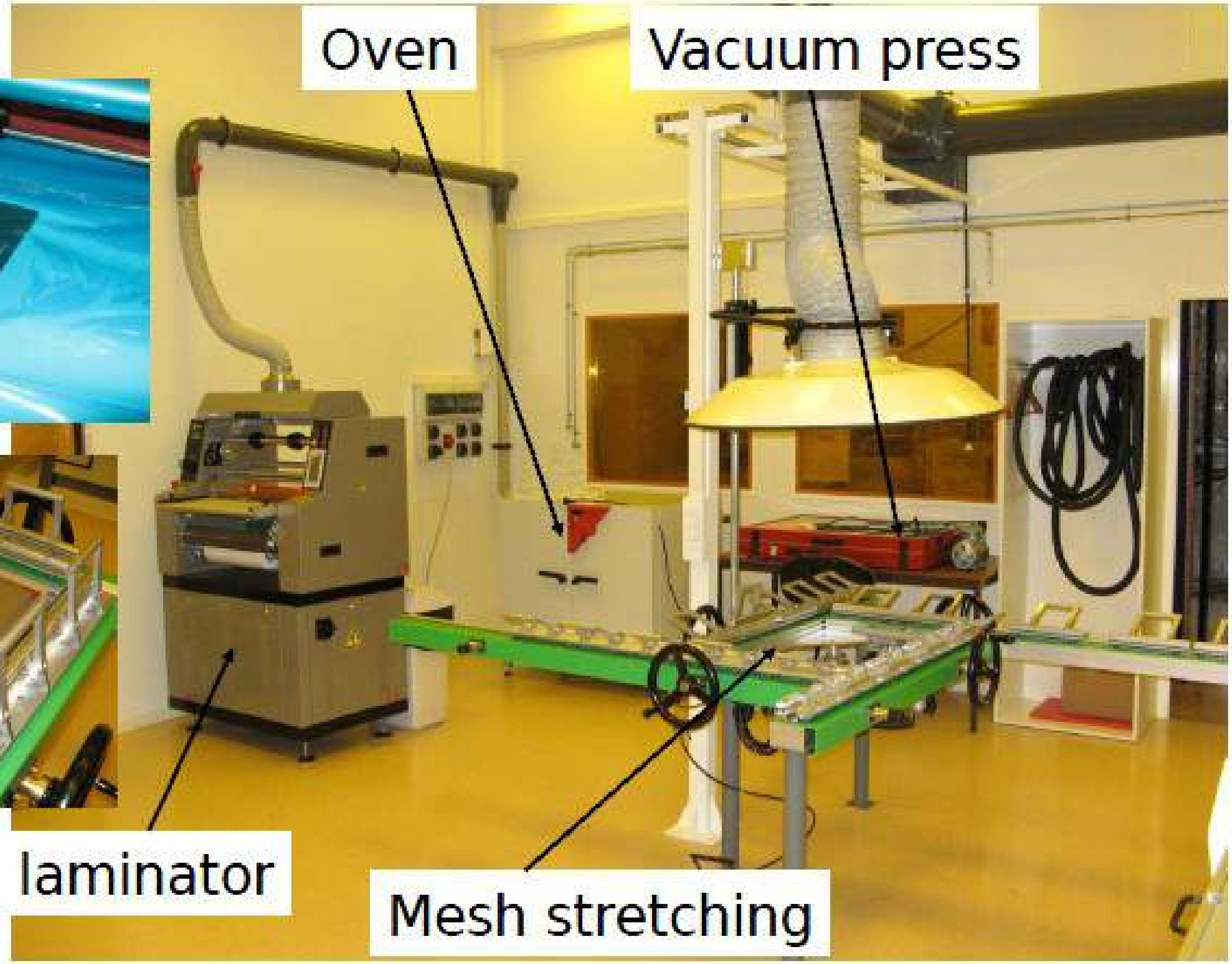




The bulk lab @ SEDI, CEA Saclay

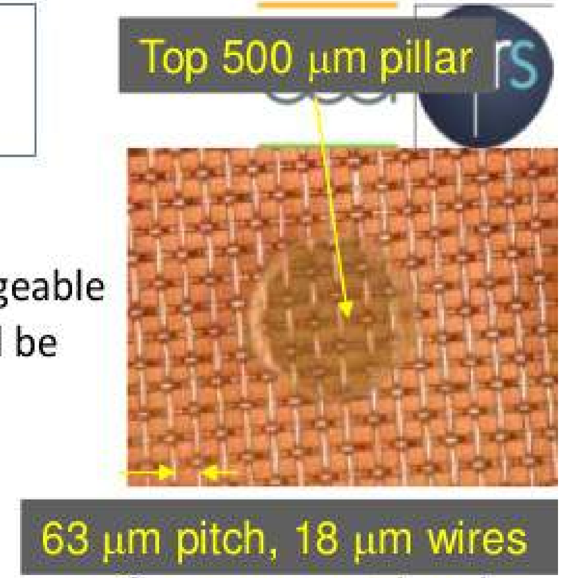


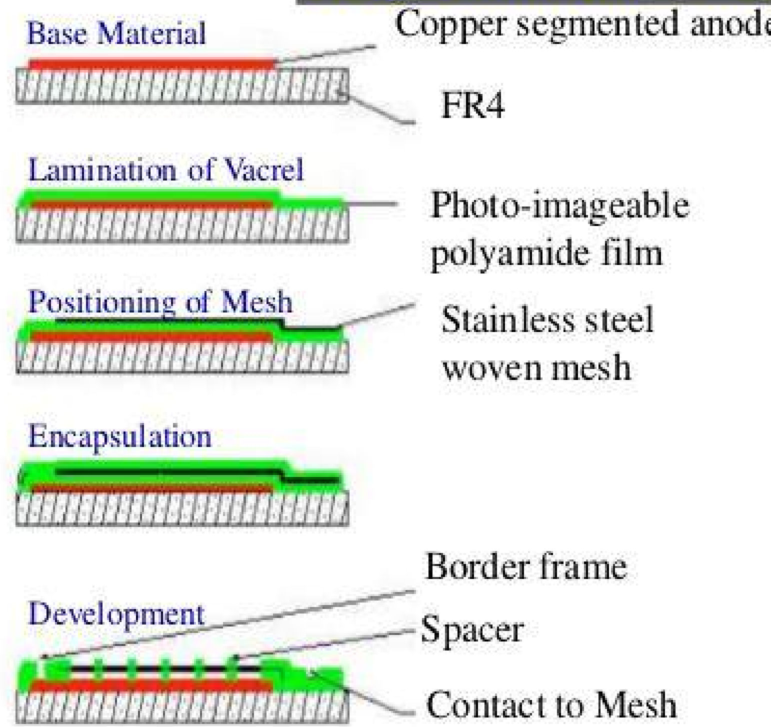




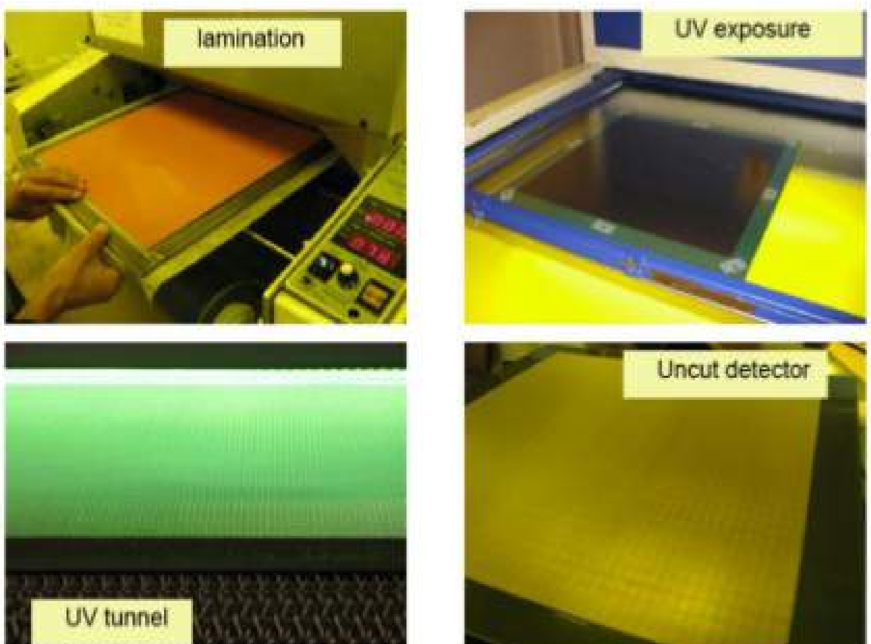
The bulk-micromegas

- First prototypes in 2004. CERN-TS-DEM/Irfu collaboration
- A woven micro-mesh is embeded between 2 layers of photo-imageable material. Amplification gap of 128 μm is standard, 104 μm should be ok, 64 μm is tricky
- No farme, no mechanics → % level dead zones
- Up to 40x40 cm^2 is standard
- Robust, Industrial process





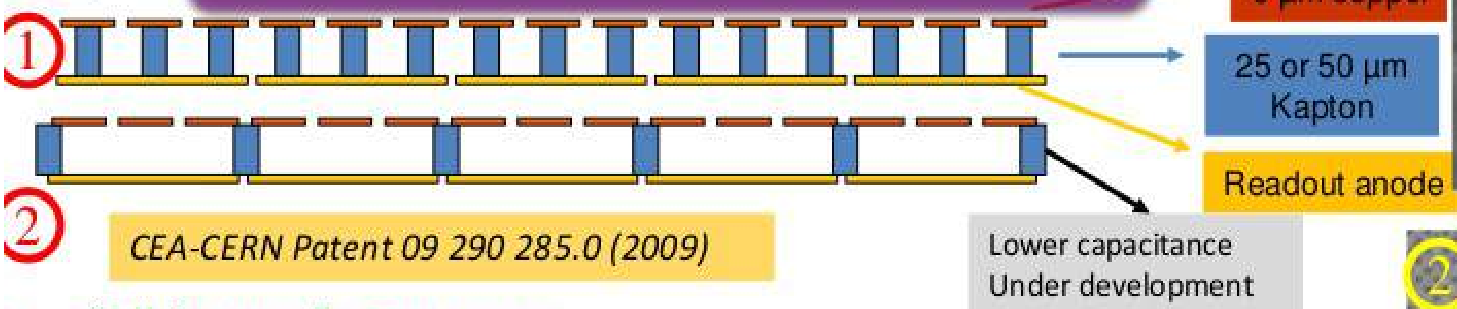
Ref: I. Giomataris *et.al.*, NIM A560 (2006) 405



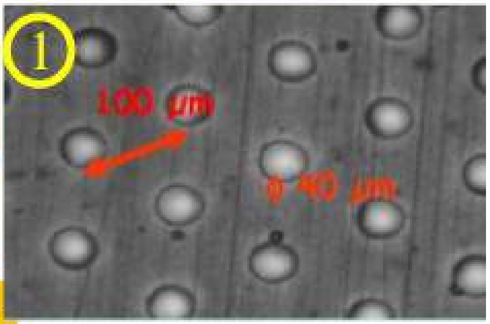
alain.delbart@cea.fr

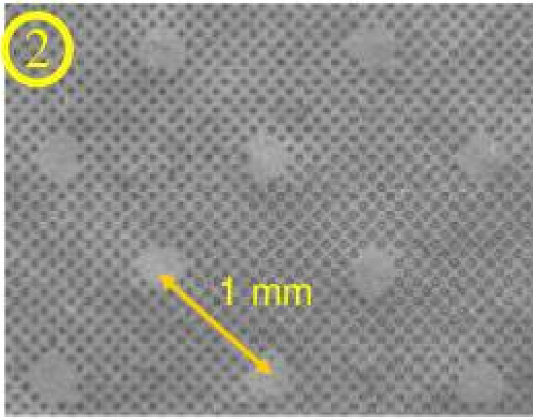
The micro-bulk micromegas

Same manufacturing techniques as GEM :
Copper & Kapton etching of a copper cladded Kapton



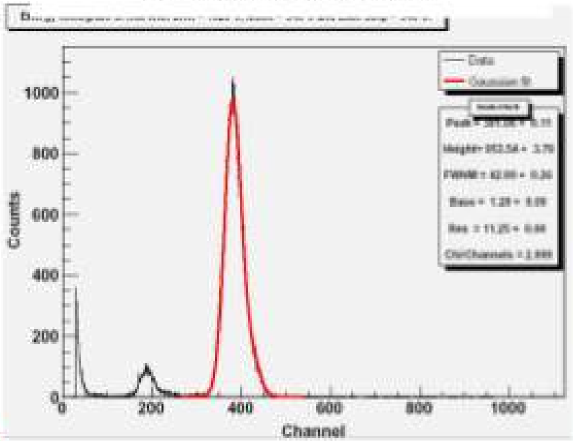
CEA-CERN Patent 09 290 285.0 (2009)

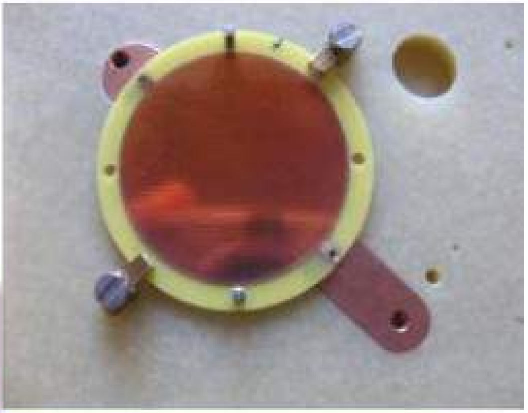




- "All-in one" structure mesh+anode
- Excellent Energy resolution
  11% FWHM @ 5,9 keV, 6 % @ 22 keV, 1,5 % @ 5 MeV)
- Good uniformity
- Low materiel budget detector
- Flexible structure
- Low intrinsic radioactivity
- Fabrication process still improving
- Fragile
- Limited sizes (<100 cm²)

11% FWHM at 5.9 keV
Ar + 5% Iso at **1 bar**





Better mesh transparency &
12 µm gap under development

Ref: S. Aune et al. NIM A 604, 15-19, 2009
S. Andriamonje et al. JINST 4, MPGD2009 conf. proceedings

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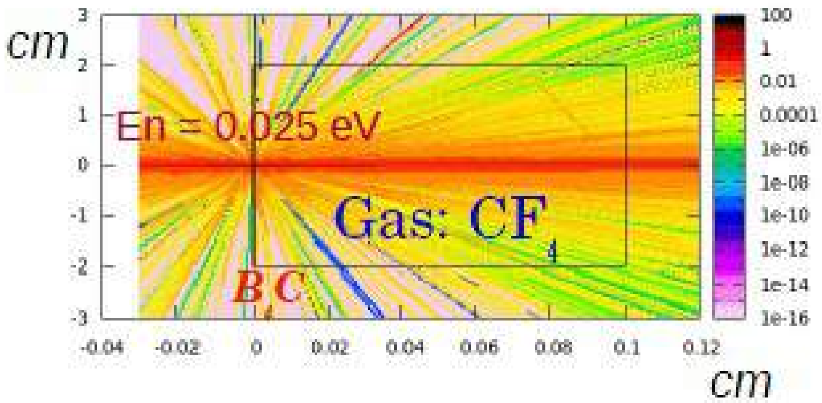
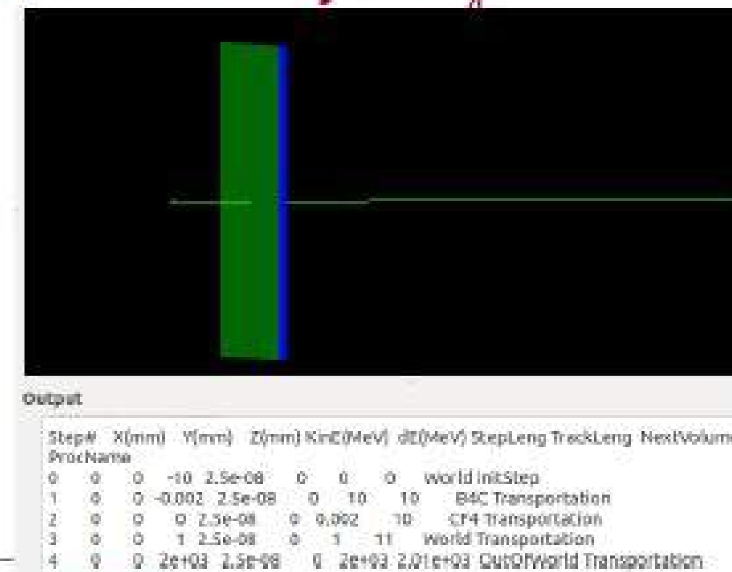
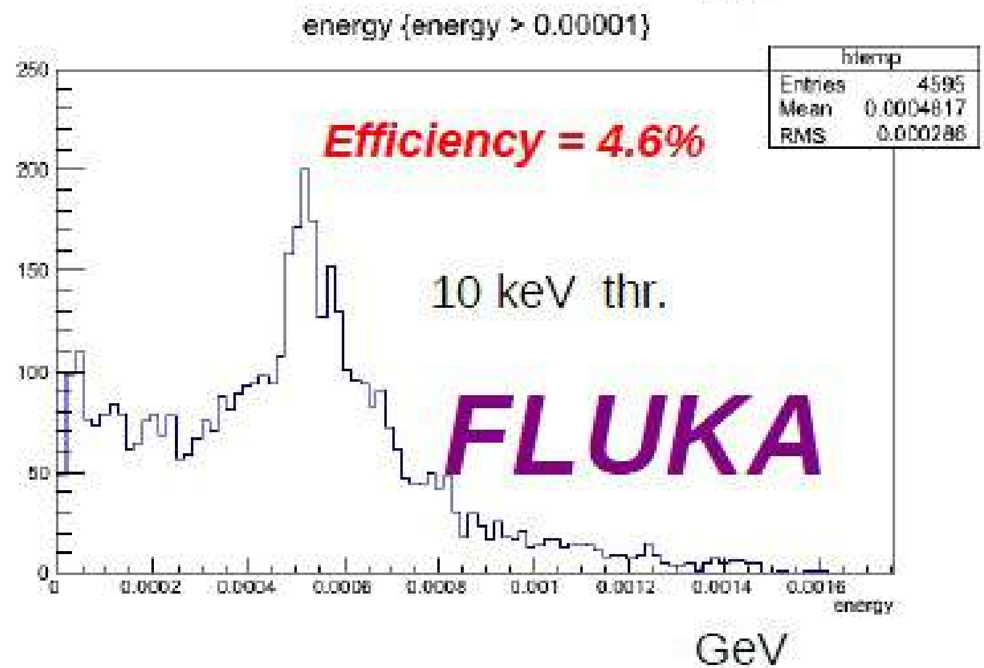
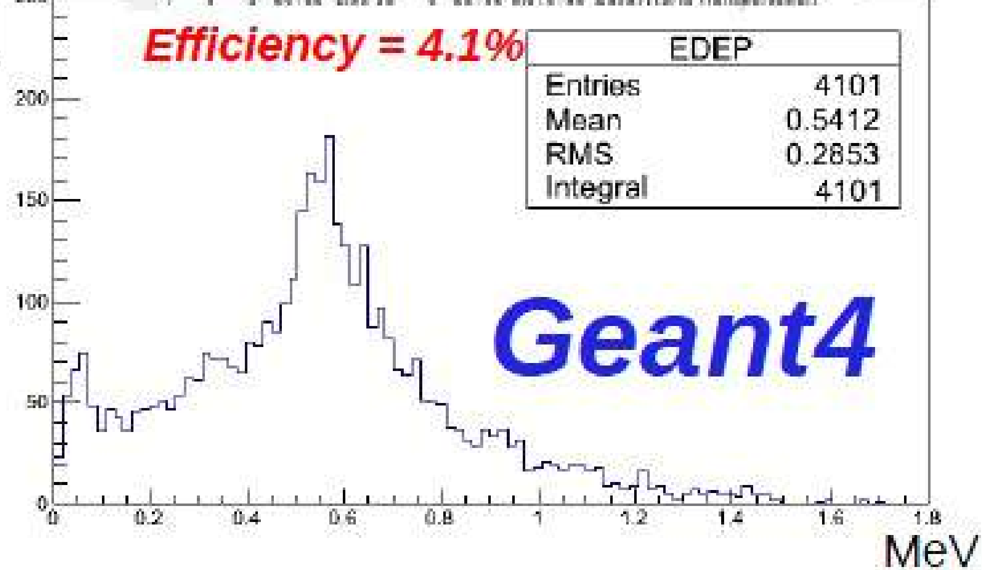
FLUKA vs Geant4 at E_{thr} > 10 keV

Event-by-Event E deposition spectra: perpendicular beam with En = 0.025 eV, 2μm B_4C, 1E5 primaries – 1 layer B_4C







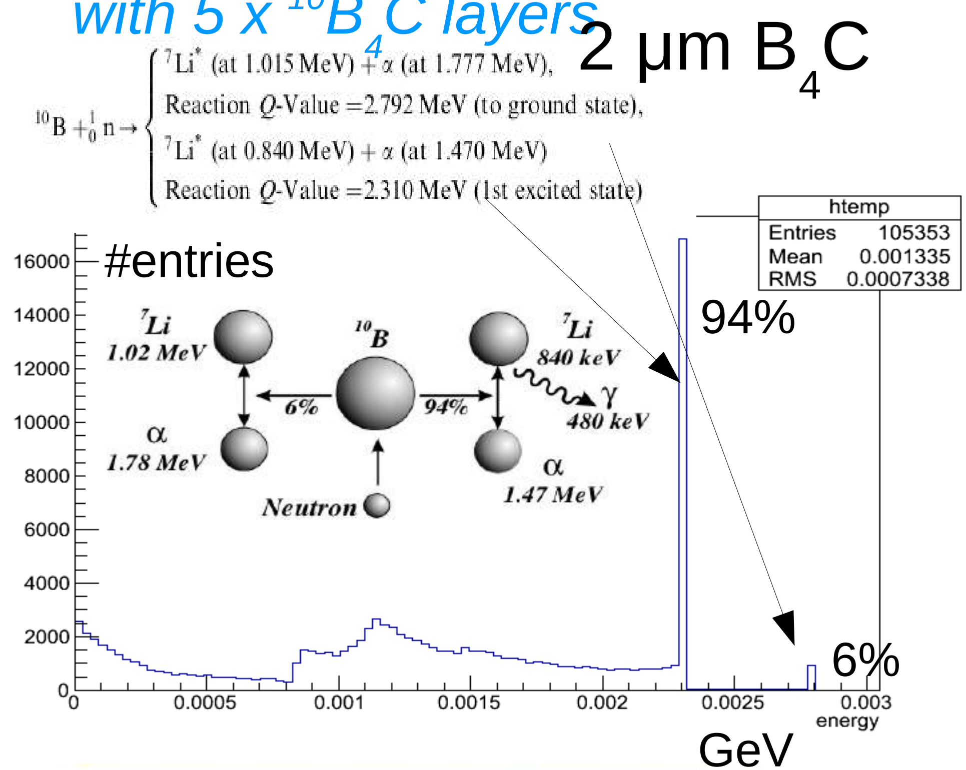


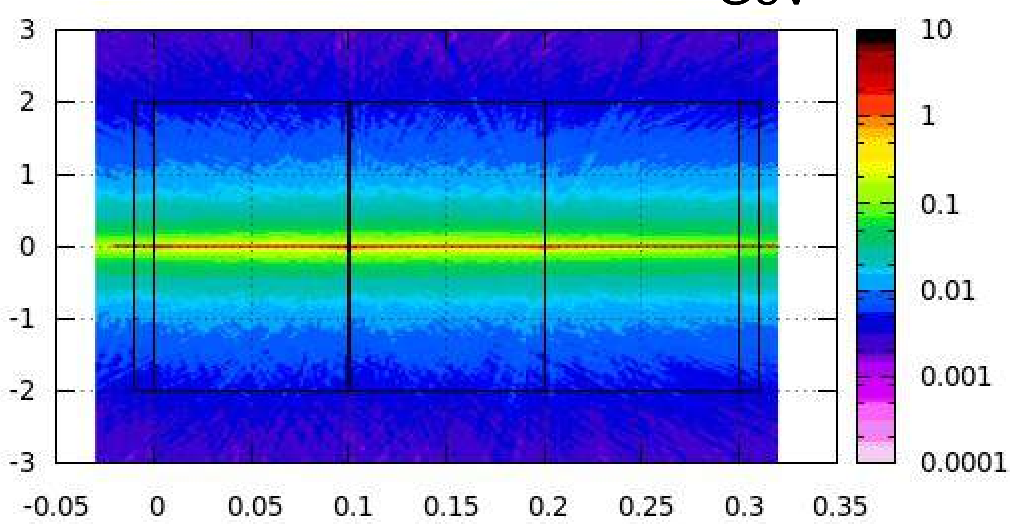
11% discrepancy

Event-by-Event E deposition spectra: perpendicular beam on the Al frame with En = 0.025 eV, Eth = 1 keV, 2μm B_4C, 1E6 primaries

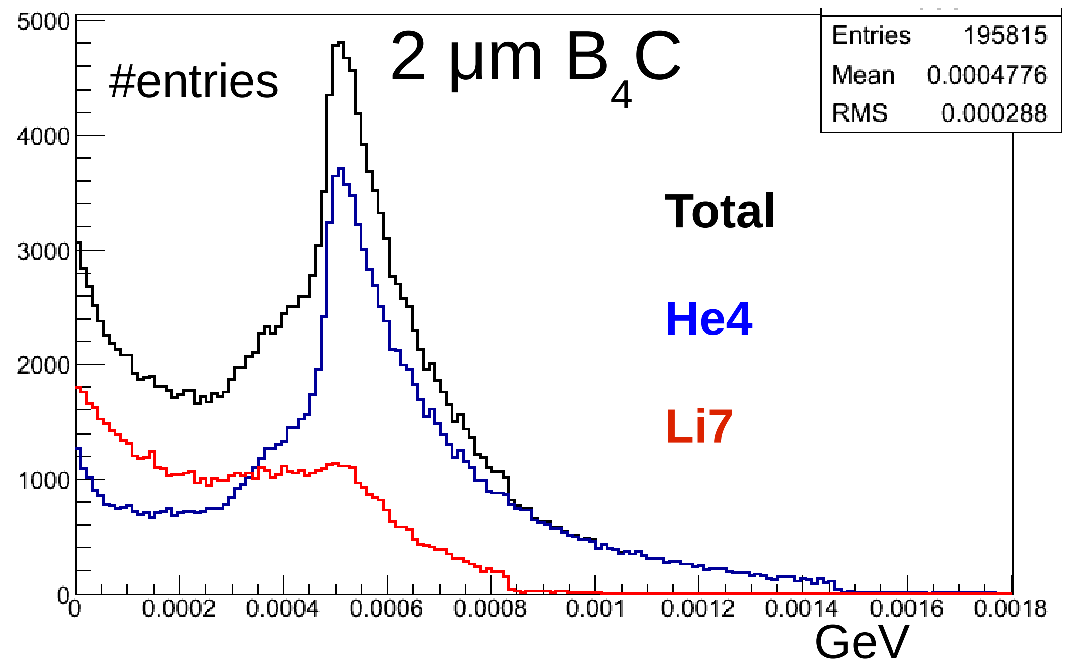
Energy deposition in a converter layer B_4C

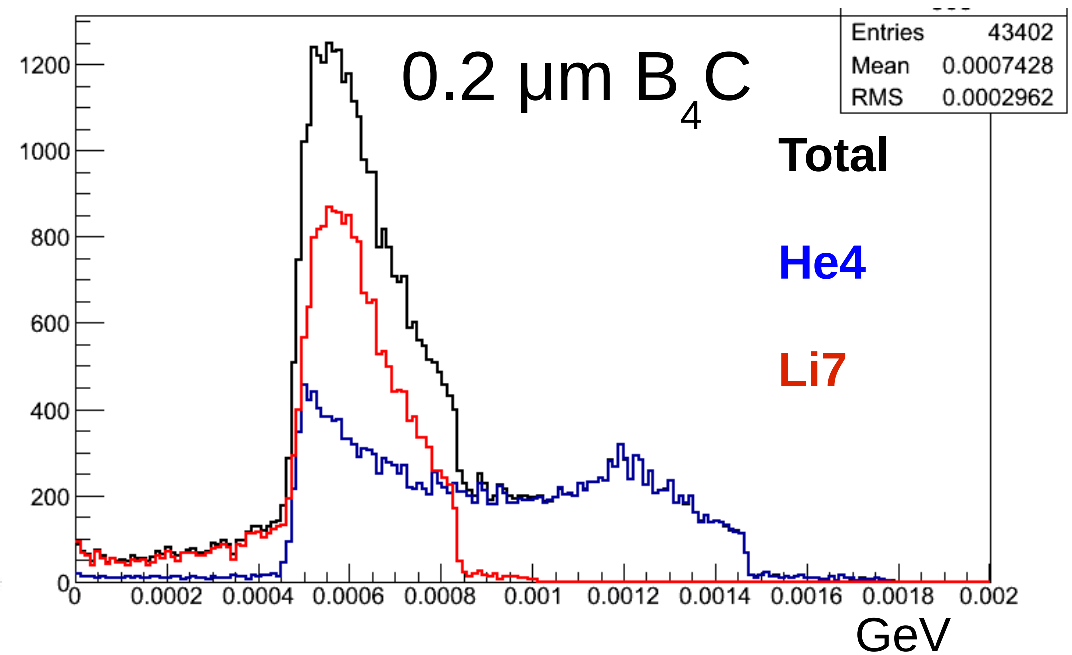
with 5 x $^{10}B_4C$ layers





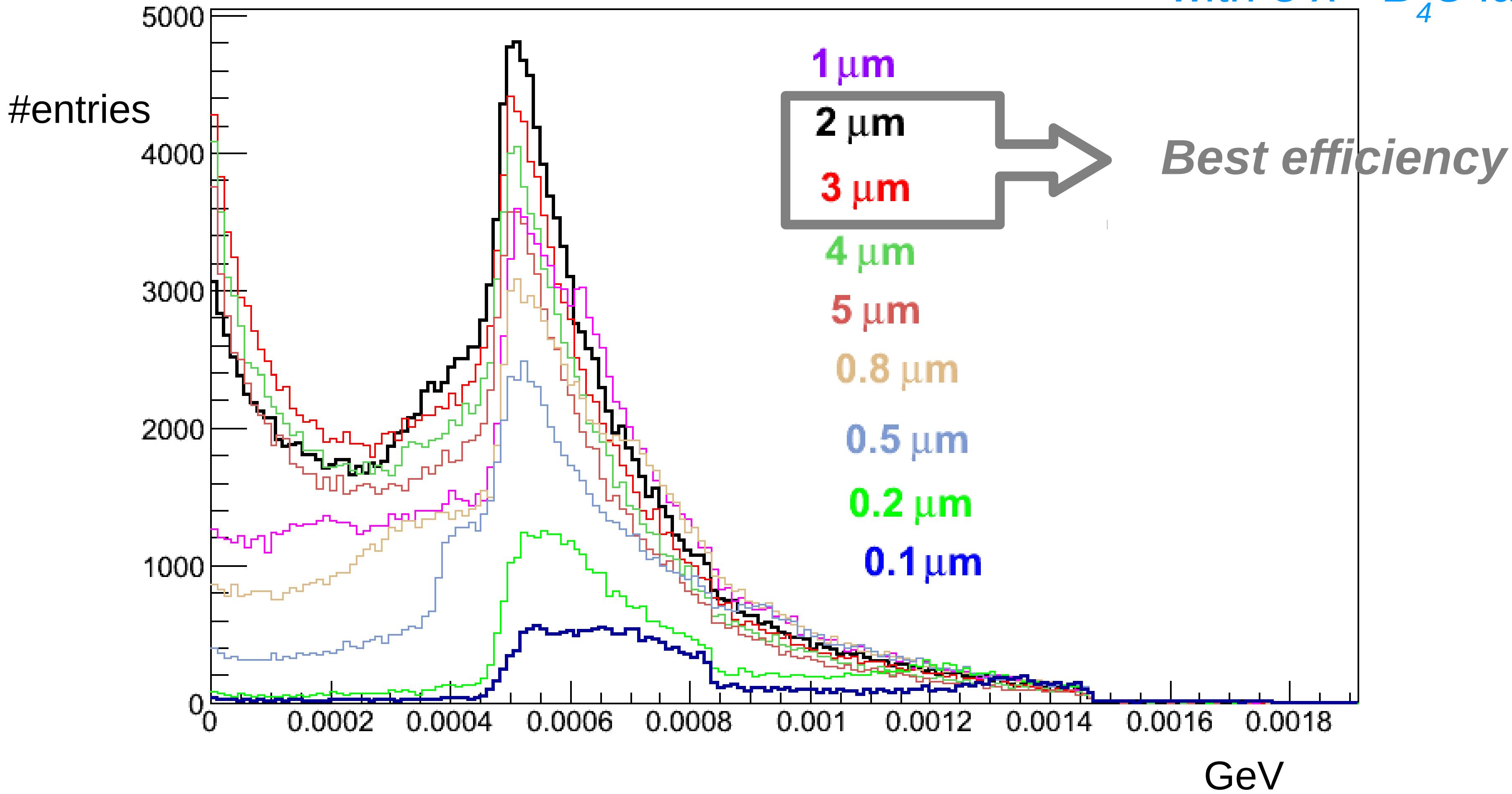
Energy deposition in the gas





Event-by-Event E deposition spectra: perpendicular beam on the Al frame with En = 0.025 eV, Eth = 1 keV, various B_4C, 1E6 primaries

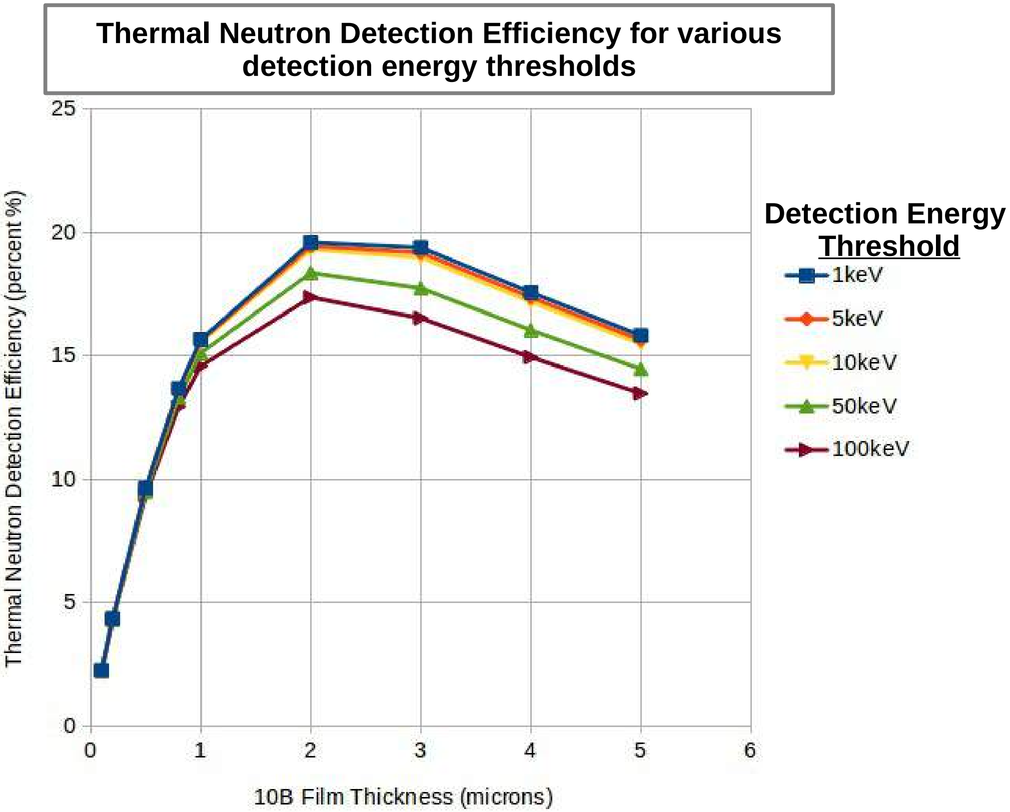
with 5 x $^{10}B_4C$ layers

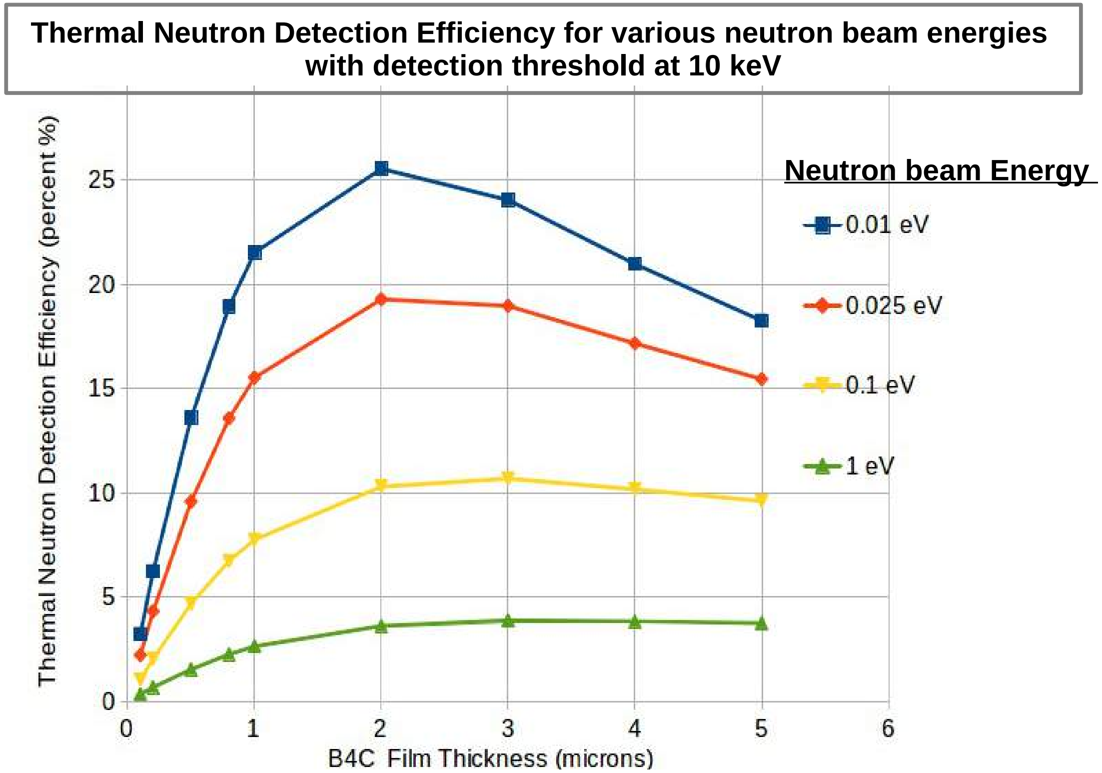


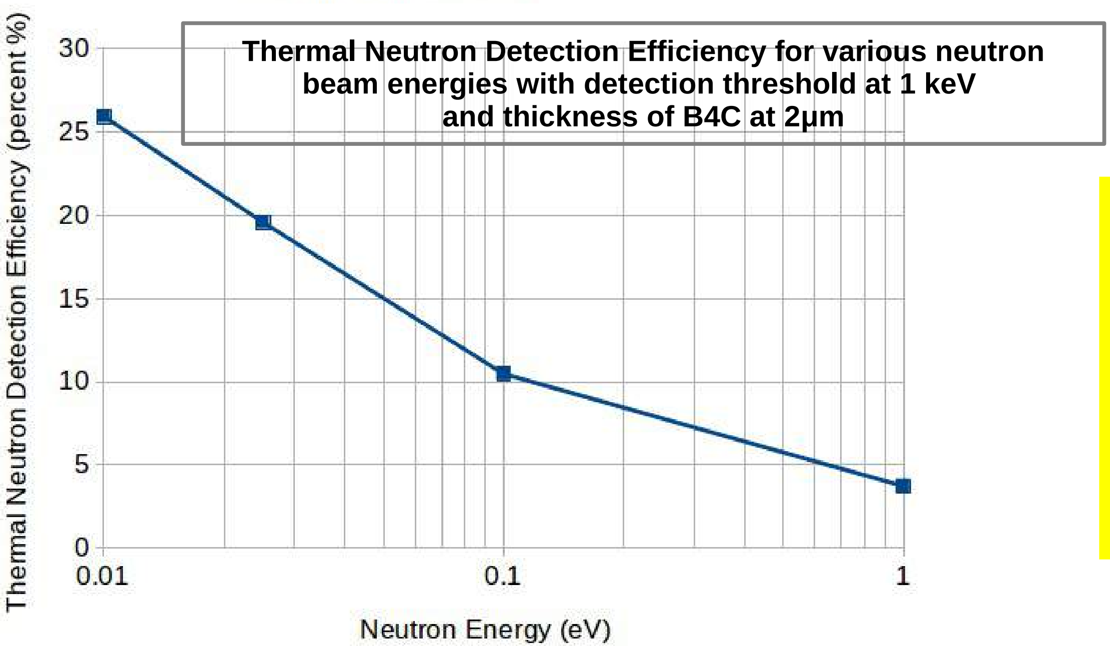
- The spectral changes as a function of ^{10}B thickness are apparent.

Energy peak resolution is best for thin ^{10}B films, whereas efficiency is highest for the thickest ^{10}B films.

Efficiency in %: perpendicular beam on the Al frame *with 5 x $^{10}B_4C$ layers*





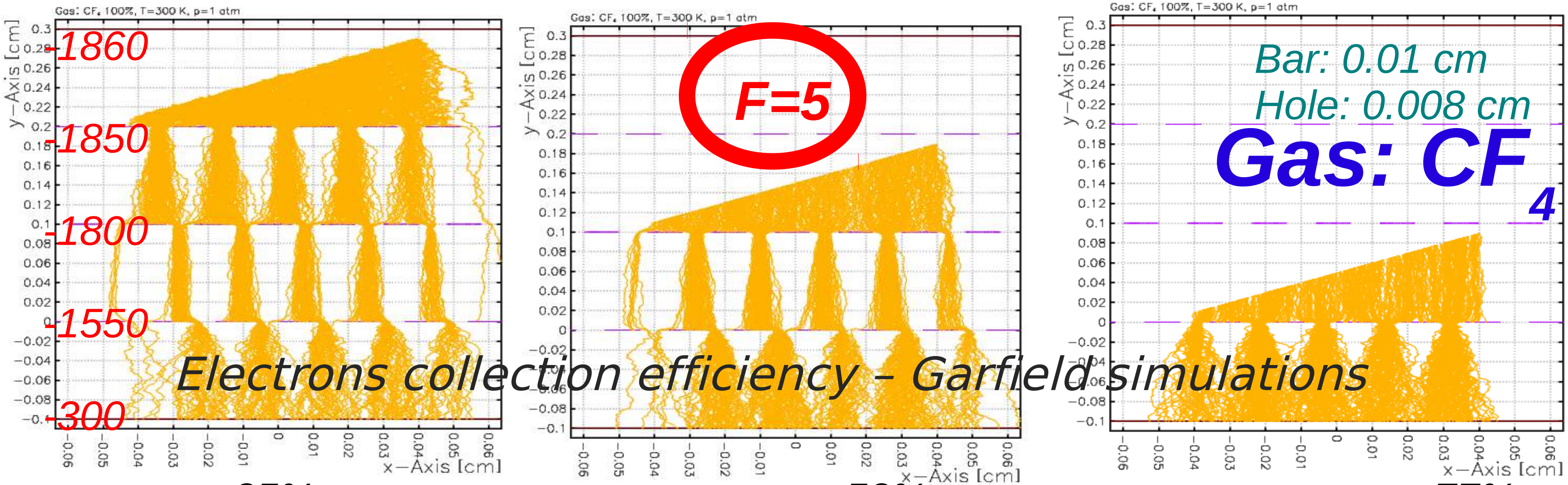


A "single 2-mesh detector unit"

- 2-3 μm of B_4C gives the best efficiency
- Can record neutron efficiencies for thermal neutron beam energies (perpendicular beam) *~ 20%*
- The aim is to build a detector capable of **> 50%** efficiency

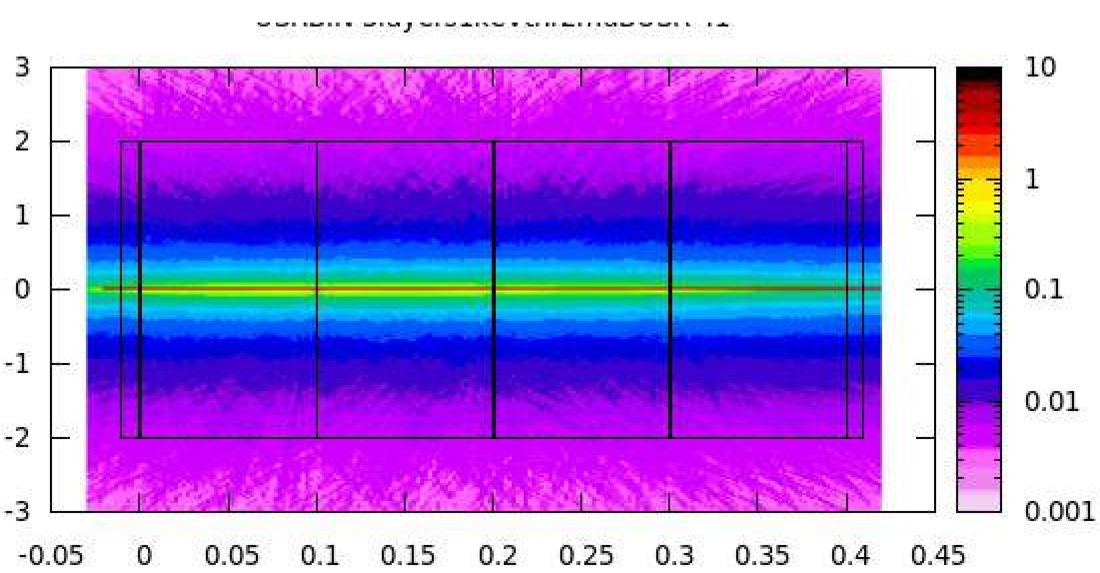
A “single 3-mesh detector unit” (7 B_4C layers)

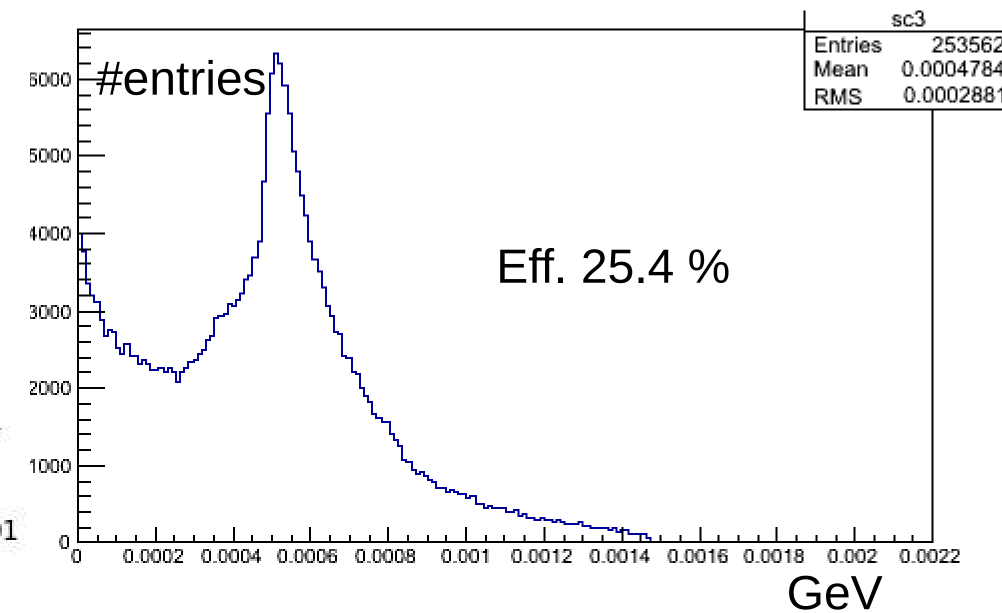
Voltages [V]



35% *53%* *77%*

Perpendicular beam on the Al frame with En = 0.025 eV,
Eth = 1 keV, 2µm B_4C – 7 layers, 1E6 primaries



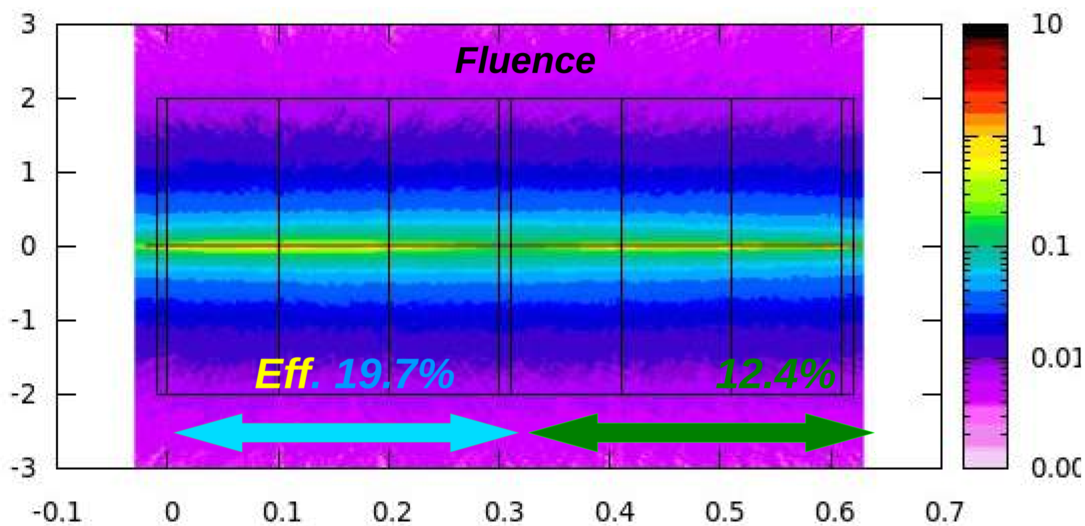


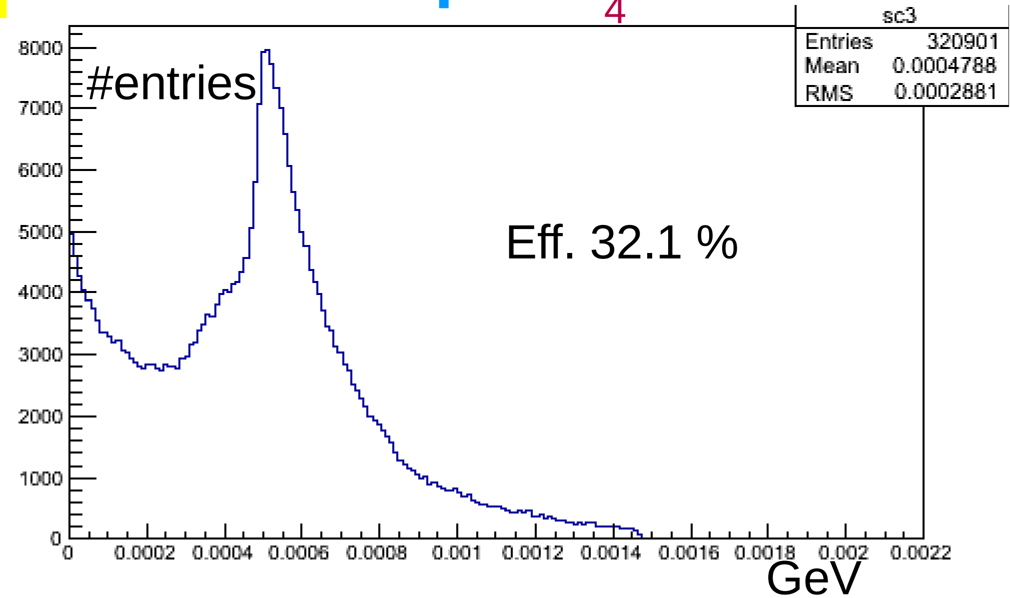
A “single 2-mesh detector unit”

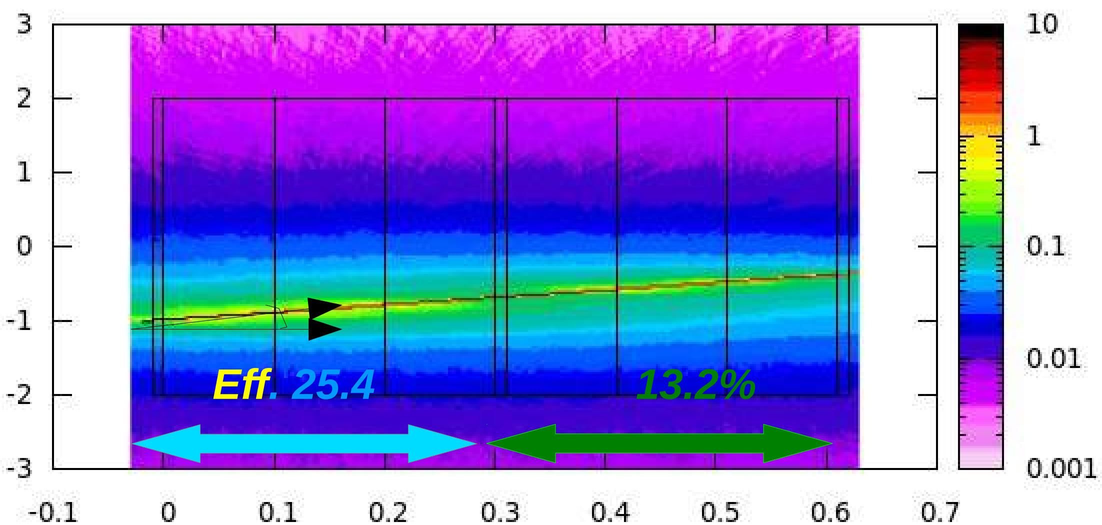
- 2-3 μm of B_4C gives the best efficiency
- Can record neutron efficiencies for thermal neutron beam energies (perpendicular beam) ~ ***20%***
- The aim is to build a detector capable of **> 50%** efficiency

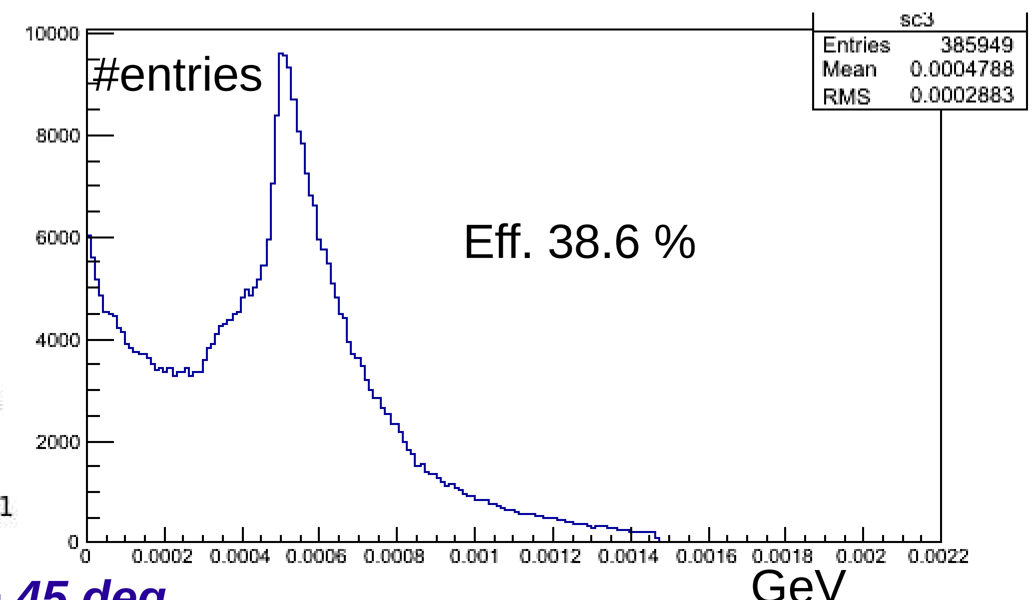
A “double 2-mesh detector unit” (10 B_4C layers)

2μm B_4C





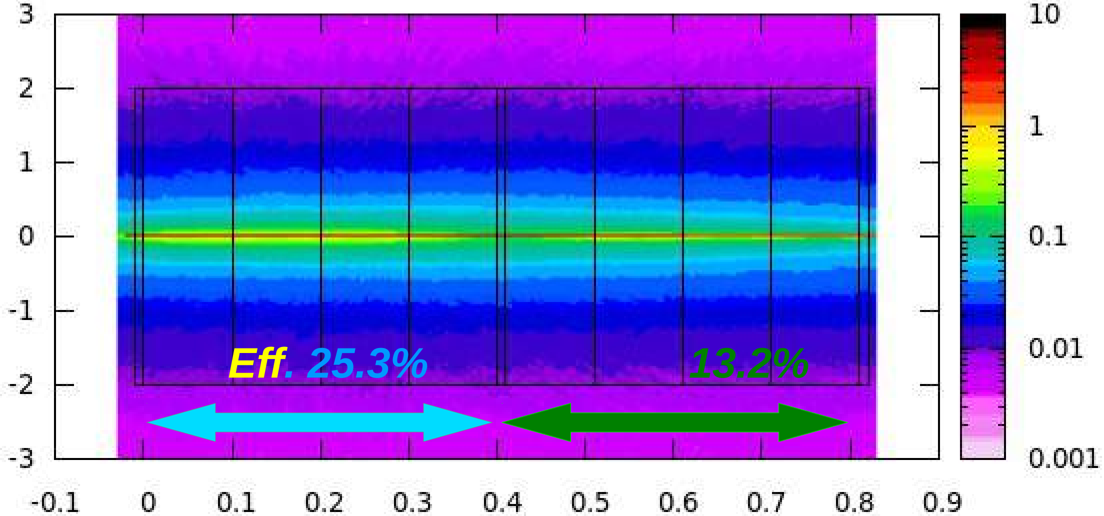


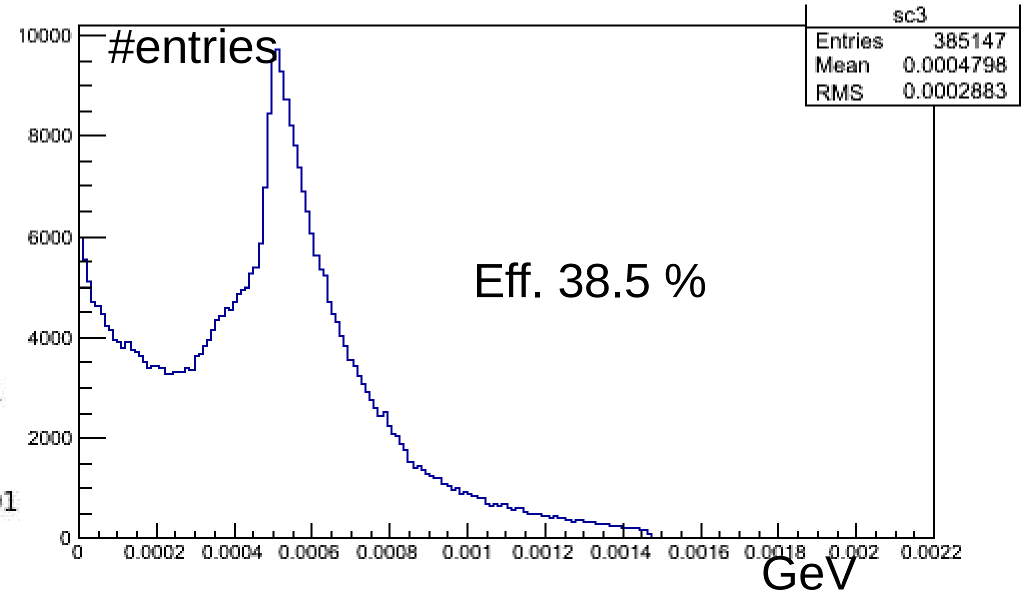


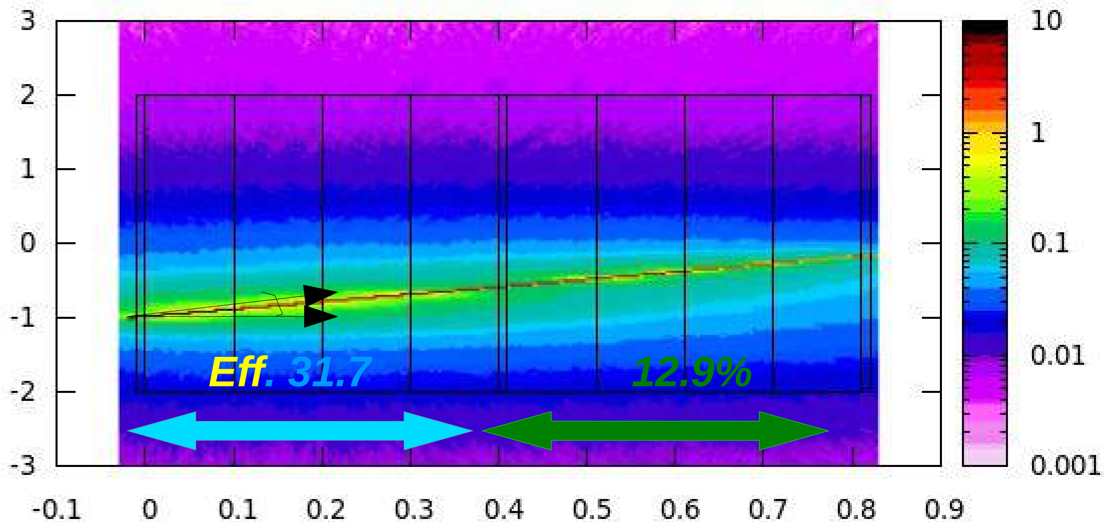
Direction cosine of beam with y-axis: 0.707 => 45 deg.

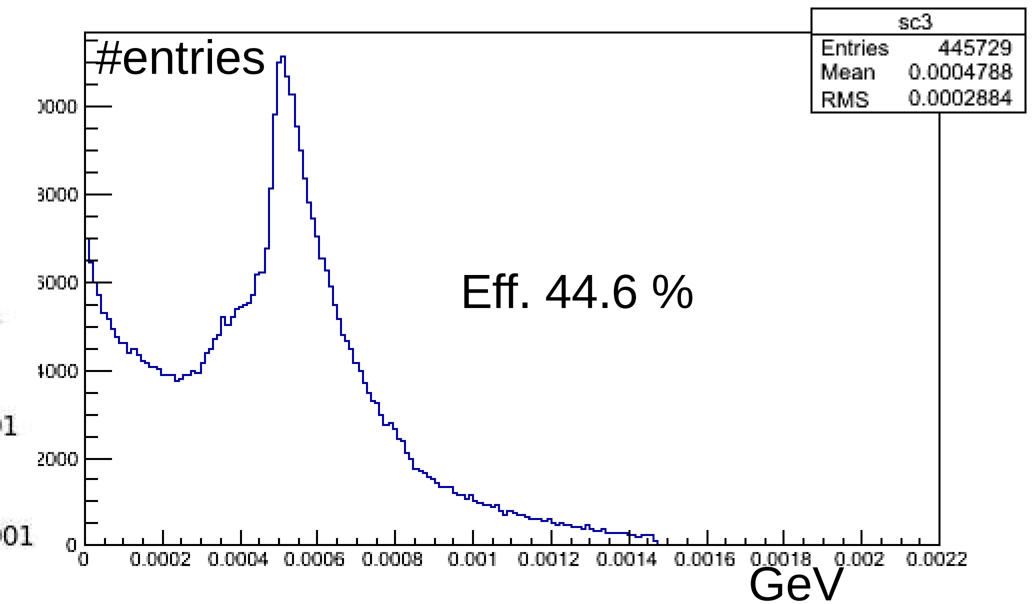
A “double 3-mesh detector unit” (14 B_4C layers)

2μm B_4C



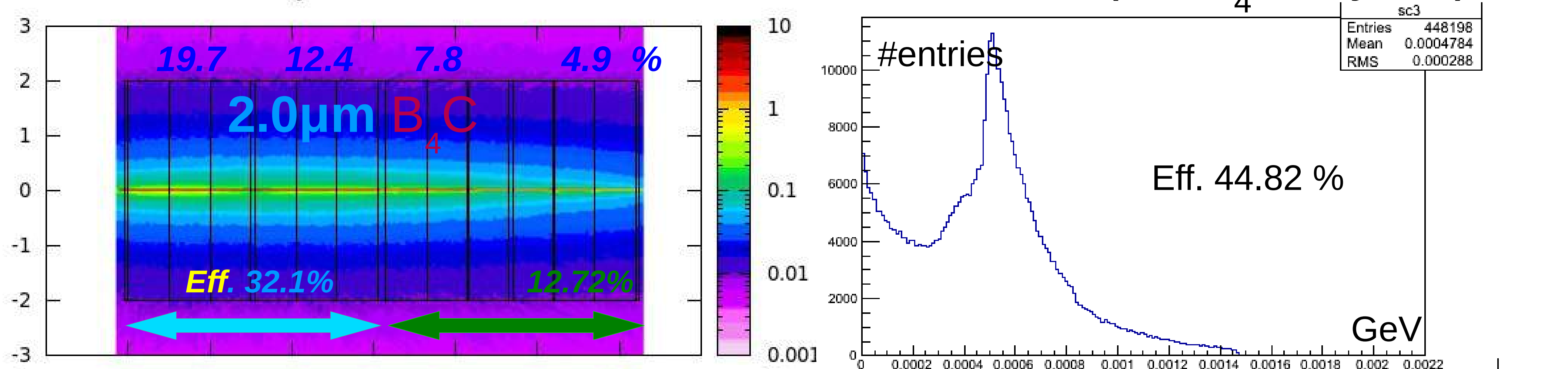


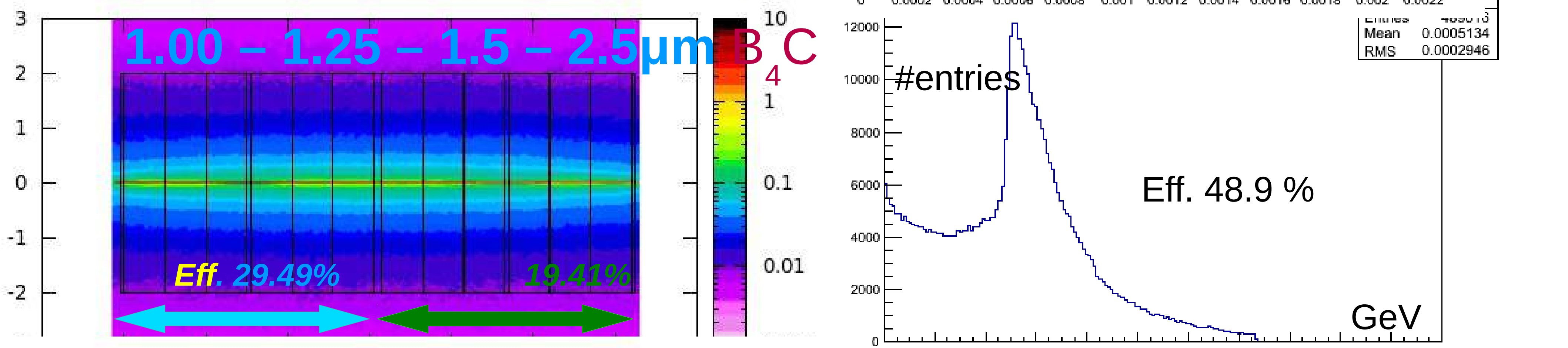


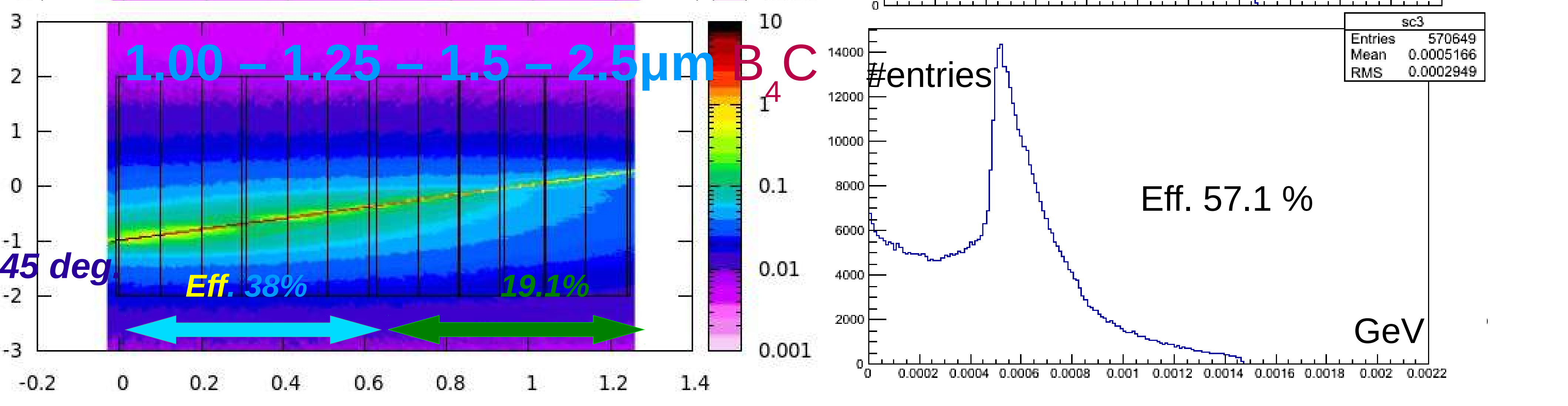


Direction cosine of beam with y-axis: 0.707 => 45 deg.

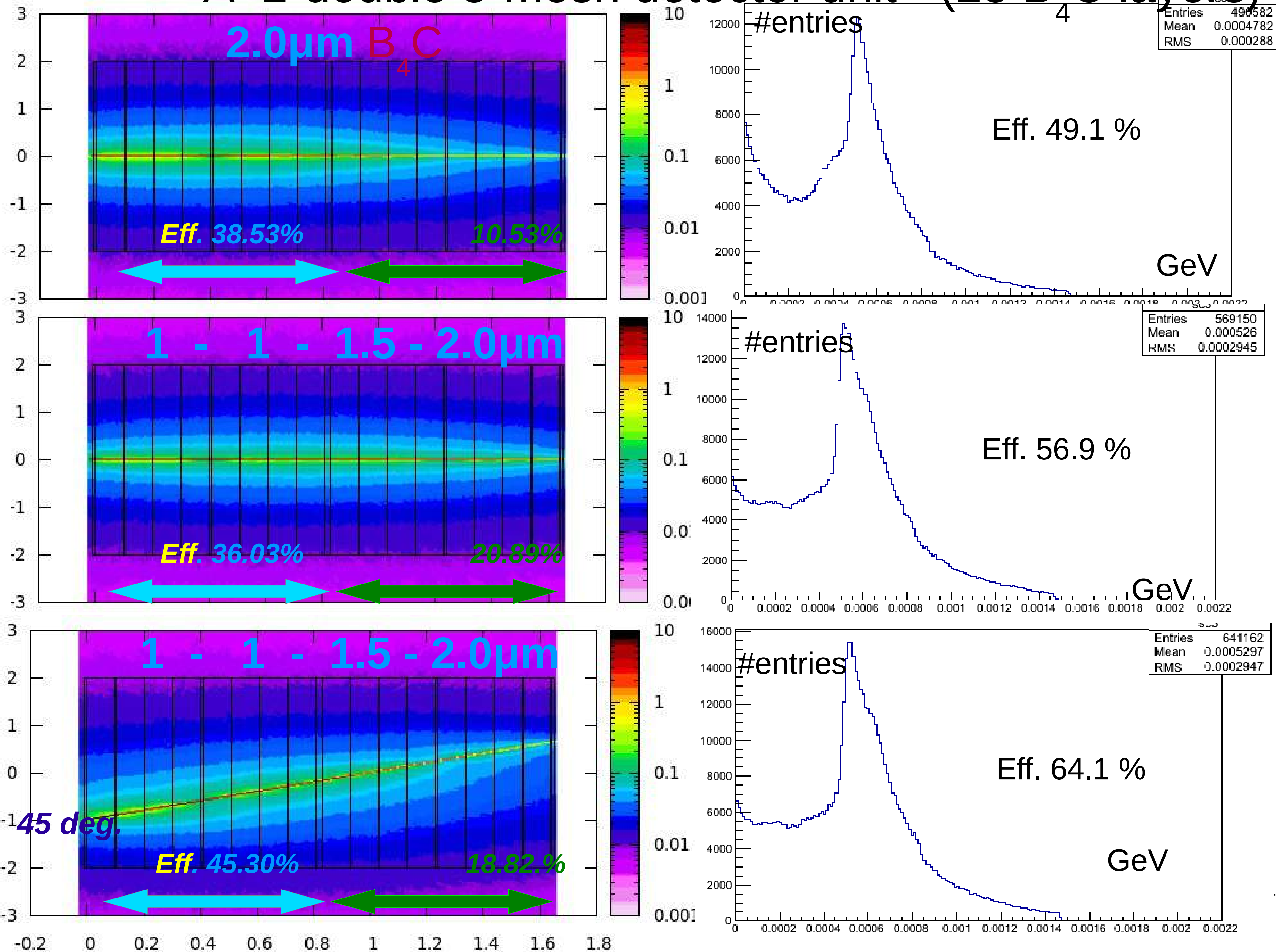
A “2-double 2-mesh detector unit” (20 B_4C layers)

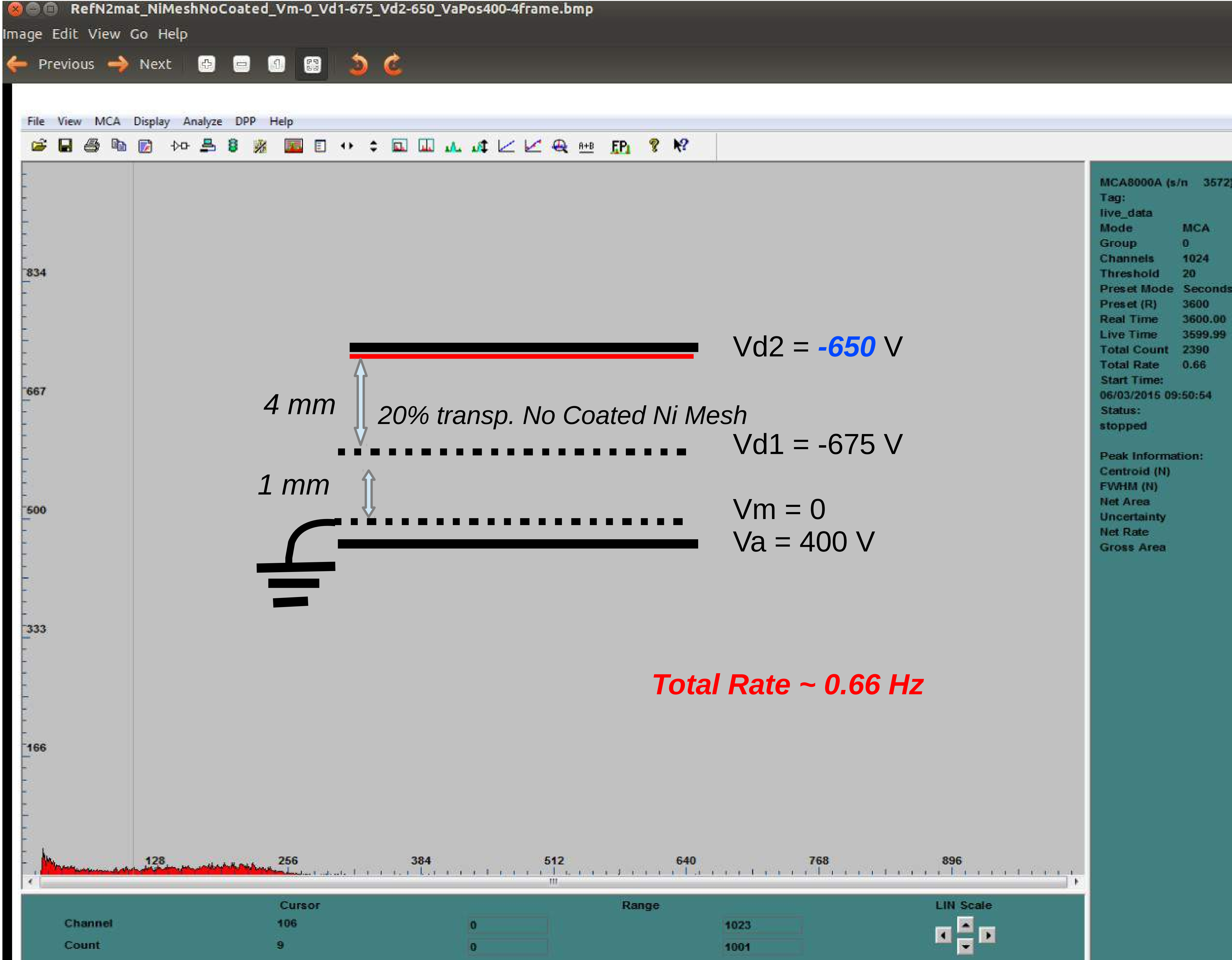


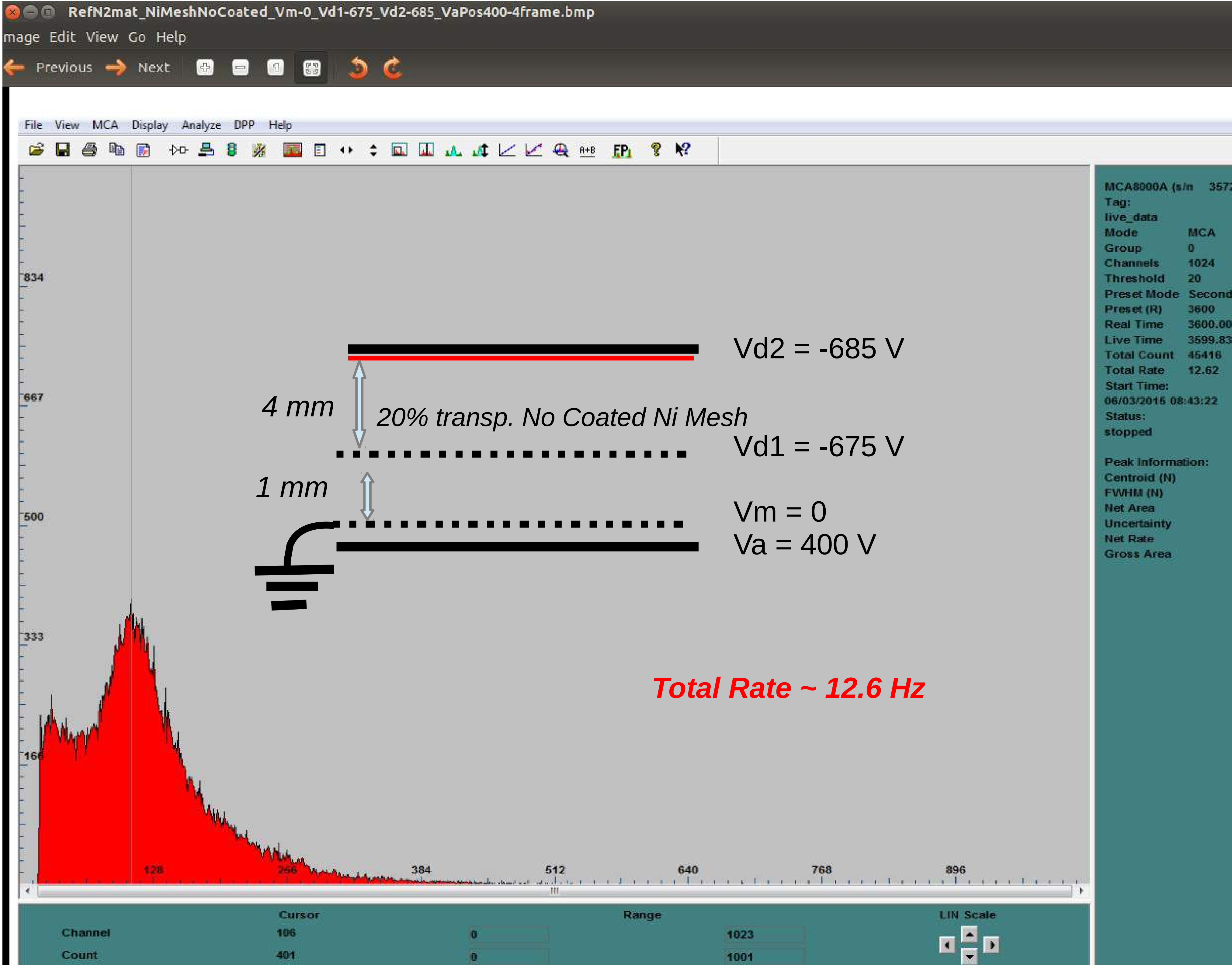




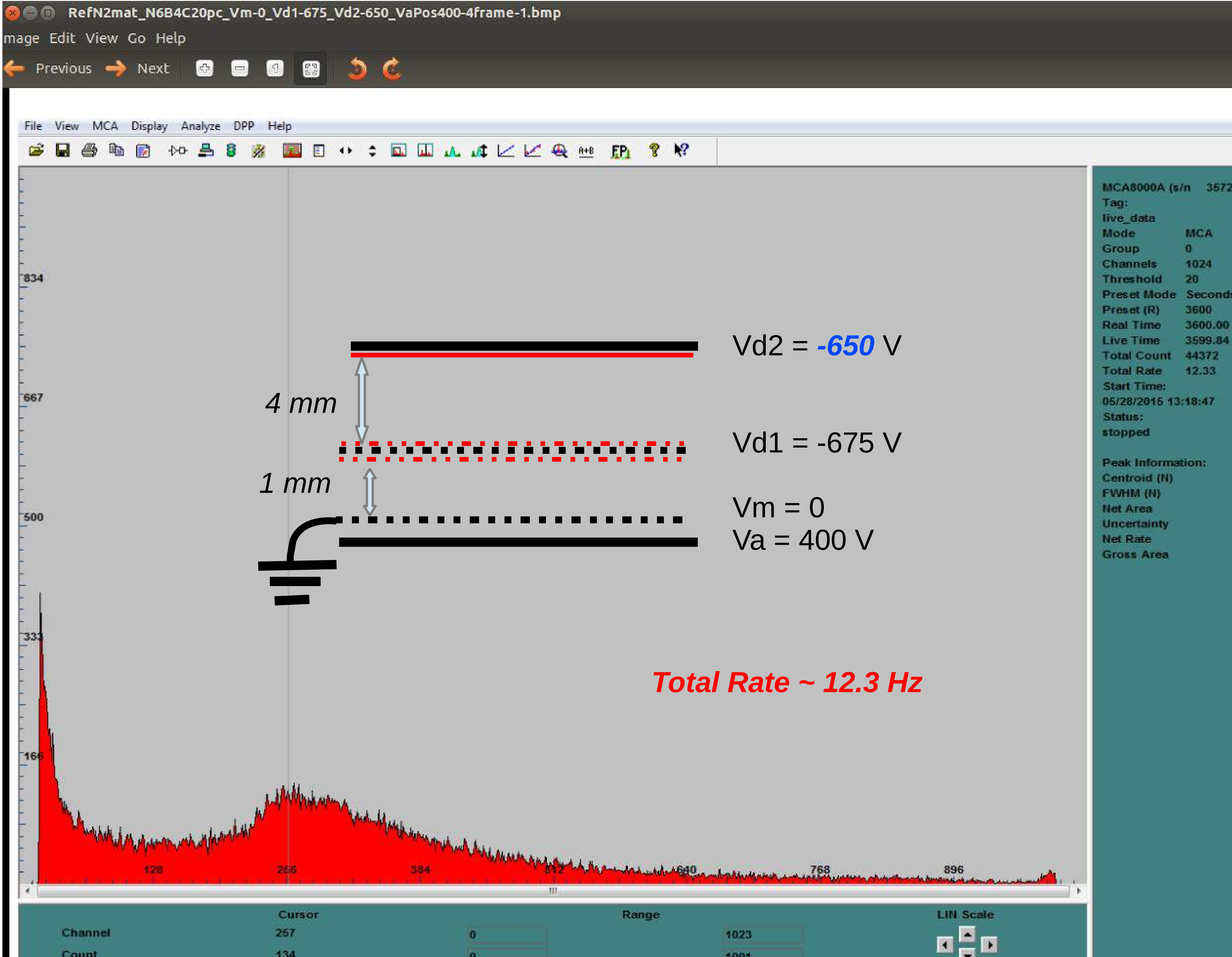
A “2-double 3-mesh detector unit” (28 B_4C layers)



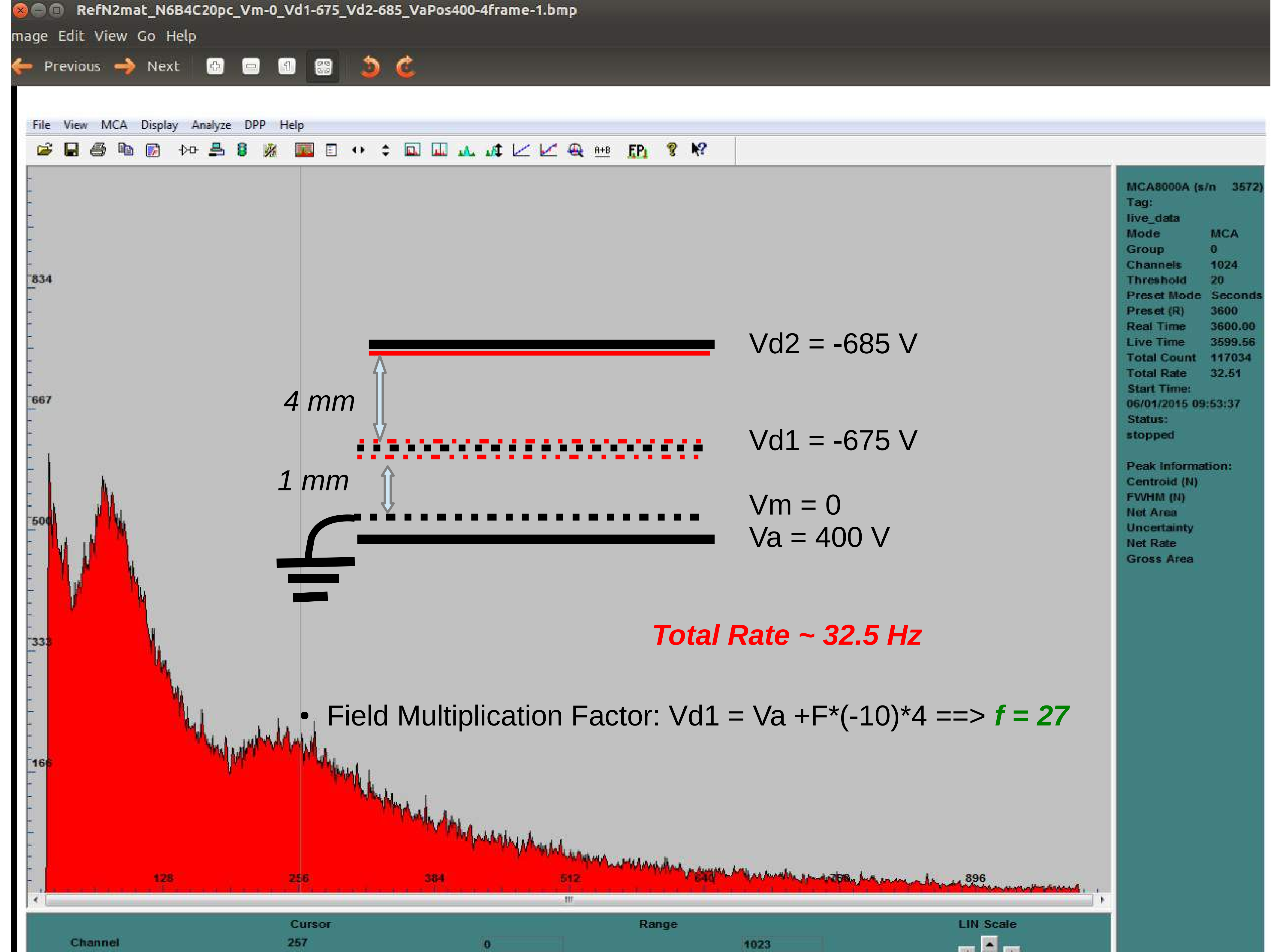

RefN2mat_NiMeshNoCoated_Vm-0_Vd1-675_Vd2-650_VaPos400-4frame.bmp
Vd2 = -650 V
4 mm
20% transp. No Coated Ni Mesh
Vd1 = -675 V
1 mm
Vm = 0
Va = 400 V
Total Rate ~ 0.66 Hz
MCA8000A (s/n 3572)
Tag:
live_data
Mode MCA
Group 0
Channels 1024
Threshold 20
Preset Mode Seconds
Preset (R) 3600
Real Time 3600.00
Live Time 3599.99
Total Count 2390
Total Rate 0.66
Start Time:
06/03/2015 09:50:54
Status:
stopped
Peak Information:
Centroid (N)
FWHM (N)
Net Area
Uncertainty
Net Rate
Gross Area
Cursor
Range
LIN Scale
Channel 106 0 1023
Count 9 0 1001



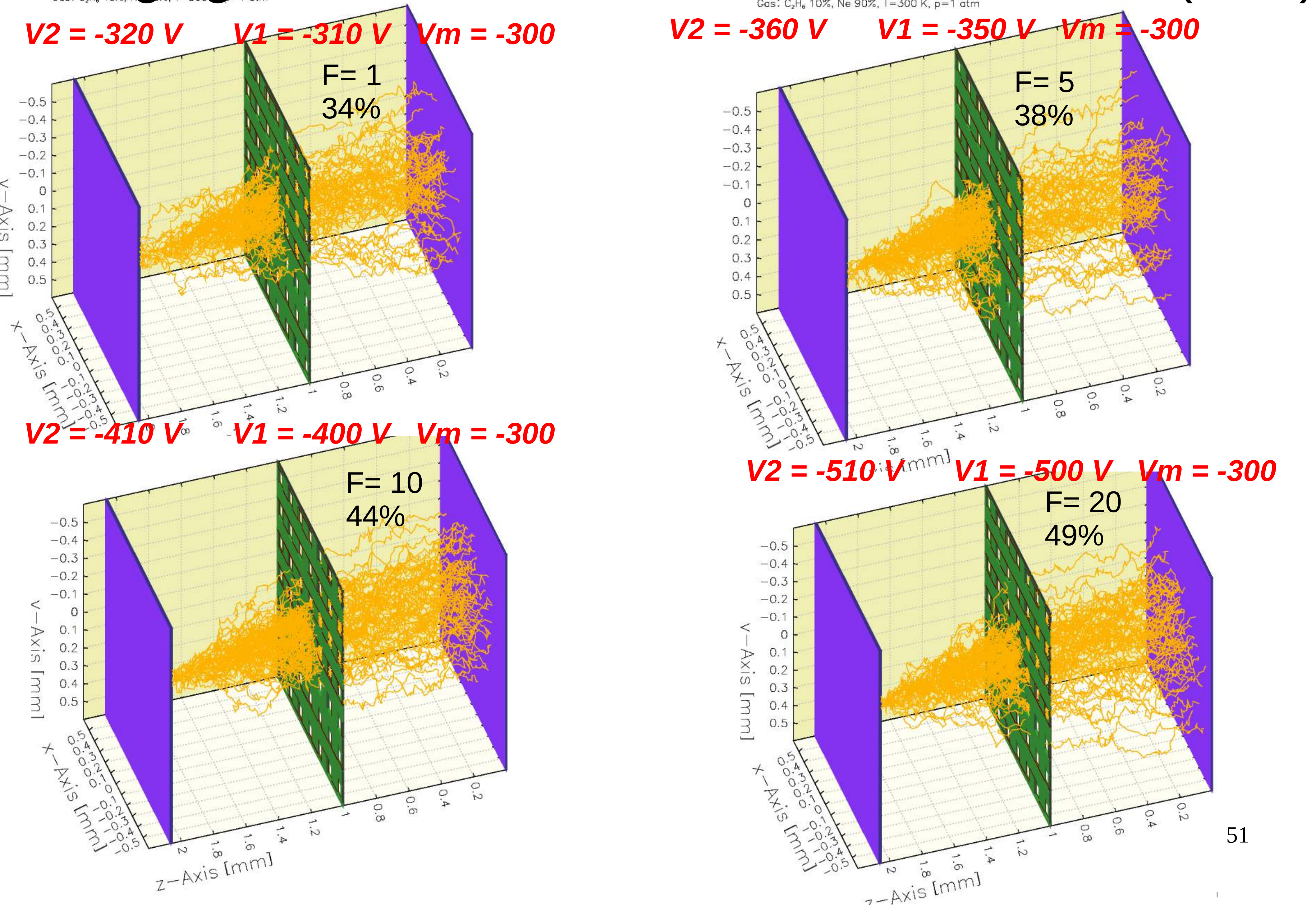
RefN2mat_NiMeshNoCoated_Vm-0_Vd1-675_Vd2-685_VaPos400-4frame.bmp
mage Edit View Go Help
Previous
Next
File View MCA Display Analyze DPP Help
834
667
500
333
166
128
256
384
512
640
768
896
Vd2 = -685 V
4 mm
20% transp. No Coated Ni Mesh
Vd1 = -675 V
1 mm
Vm = 0
Va = 400 V
Total Rate ~ 12.6 Hz
MCA8000A (s/n 3572)
Tag:
live_data
Mode MCA
Group 0
Channels 1024
Threshold 20
Preset Mode Seconds
Preset (R) 3600
Real Time 3600.00
Live Time 3599.83
Total Count 45416
Total Rate 12.62
Start Time:
06/03/2015 08:43:22
Status:
stopped
Peak Information:
Centroid (N)
FWHM (N)
Net Area
Uncertainty
Net Rate
Gross Area
Cursor
Range
LIN Scale
Channel 106 0 1023
Count 401 0 1001



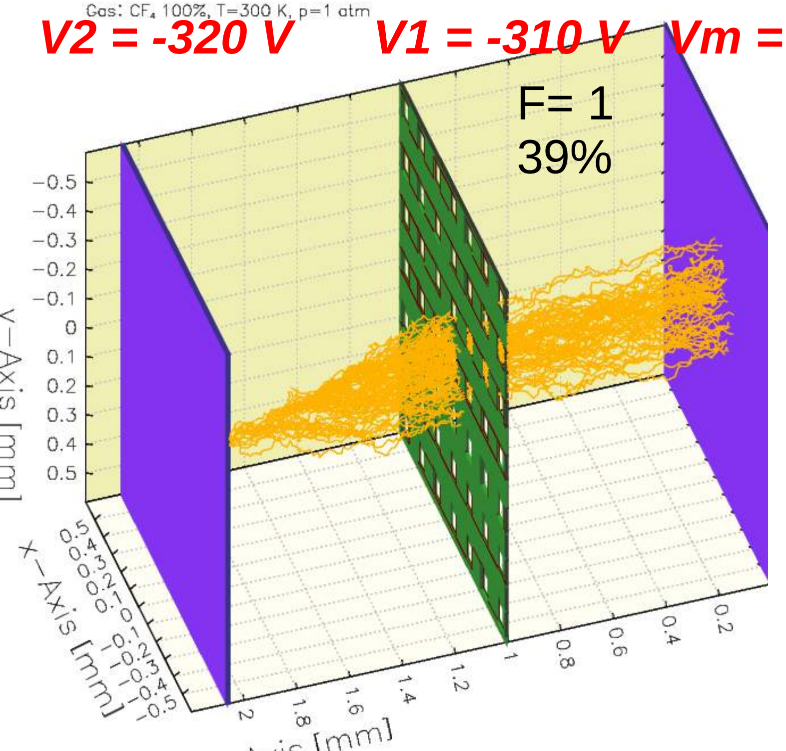
RefN2mat_N6B4C20pc_Vm-0_Vd1-675_Vd2-650_VaPos400-4frame-1.bmp
mage Edit View Go Help
Previous Next
File View MCA Display Analyze DPP Help
Vd2 = -650 V
4 mm
Vd1 = -675 V
1 mm
Vm = 0
Va = 400 V
Total Rate ~ 12.3 Hz
834
667
500
333
166
128
256
384
512
640
768
896
MCA8000A (s/n 3572)
Tag:
live_data
Mode MCA
Group 0
Channels 1024
Threshold 20
Preset Mode Seconds
Preset (R) 3600
Real Time 3600.00
Live Time 3599.84
Total Count 44372
Total Rate 12.33
Start Time:
05/28/2015 13:18:47
Status:
stopped
Peak Information:
Centroid (N)
FWHM (N)
Net Area
Uncertainty
Net Rate
Gross Area
Cursor
Range
LIN Scale
Channel 257 0 1023
Count 134


RefN2mat_N6B4C20pc_Vm-0_Vd1-675_Vd2-685_VaPos400-4frame-1.bmp
Vd2 = -685 V
4 mm
Vd1 = -675 V
1 mm
Vm = 0
Va = 400 V
Total Rate ~ 32.5 Hz
• Field Multiplication Factor: Vd1 = Va +F*(-10)*4 ==> f = 27
MCA8000A (s/n 3572)
Tag:
live_data
Mode MCA
Group 0
Channels 1024
Threshold 20
Preset Mode Seconds
Preset (R) 3600
Real Time 3600.00
Live Time 3599.56
Total Count 117034
Total Rate 32.51
Start Time:
06/01/2015 09:53:37
Status:
stopped
Peak Information:
Centroid (N)
FWHM (N)
Net Area
Uncertainty
Net Rate
Gross Area
Cursor
Channel 257
Range
0
1023
LIN Scale

Changing f with const thickness = 7 mu: Ne,C2H6(10%)

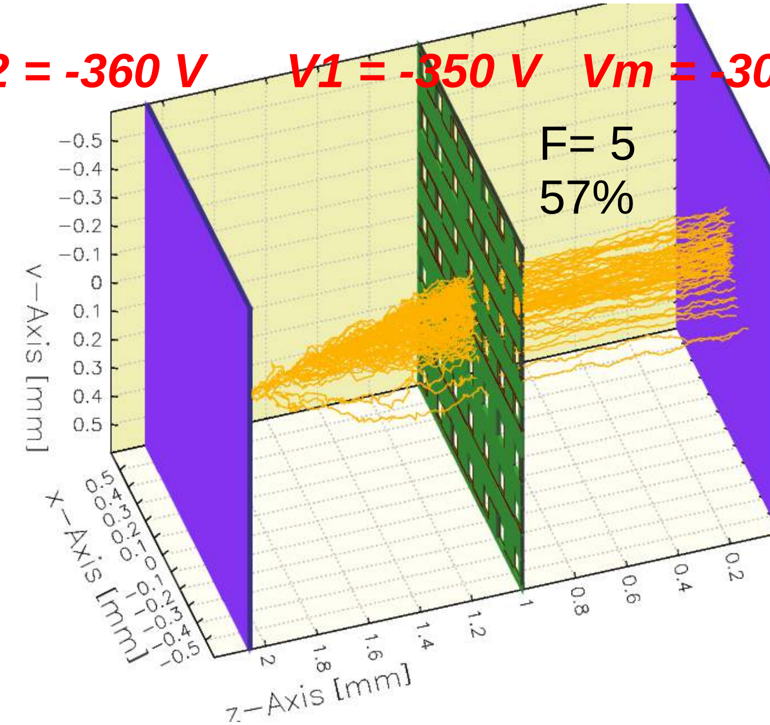


Changing f with const thickness = 7 mu: CF4



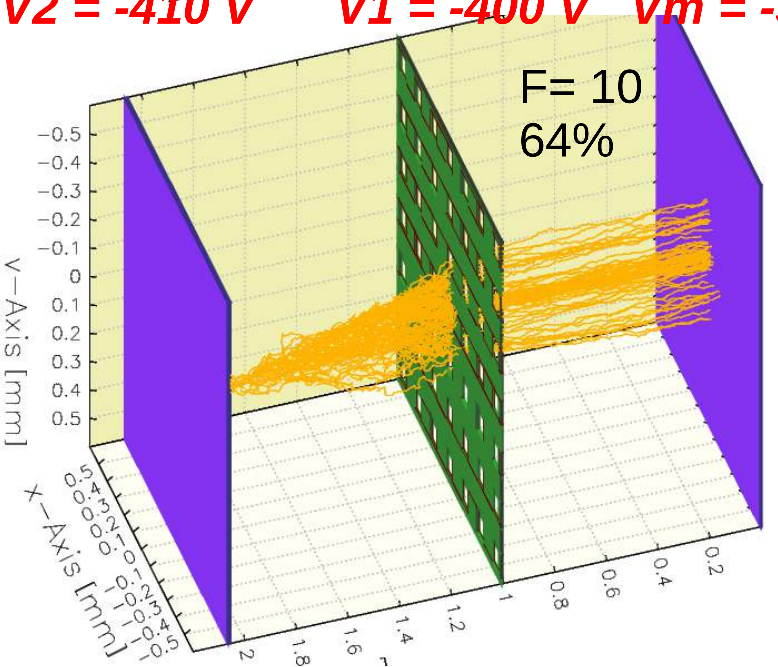
V2 = -320 V V1 = -310 V Vm = -300

F= 1
39%



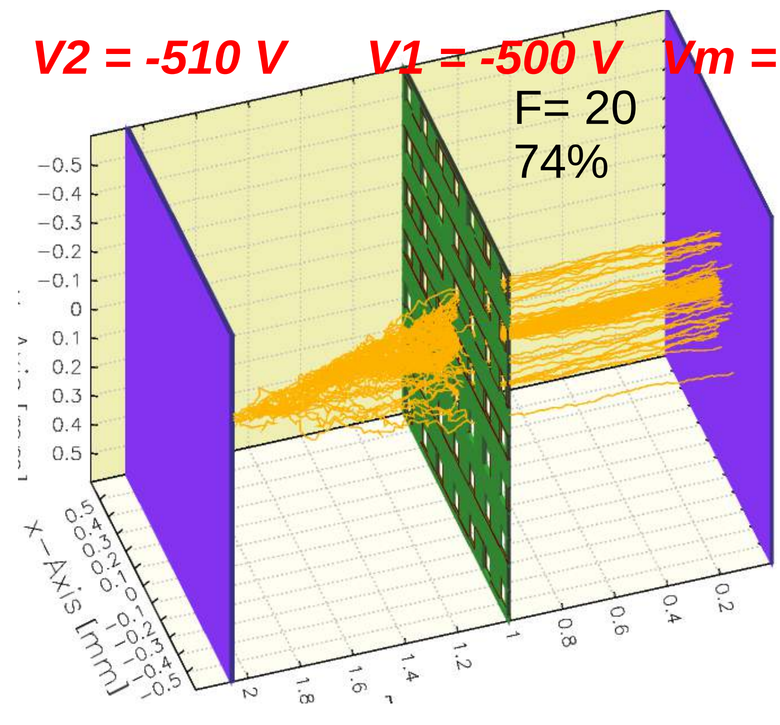
V2 = -360 V V1 = -350 V Vm = -300

F= 5
57%



V2 = -410 V V1 = -400 V Vm = -300

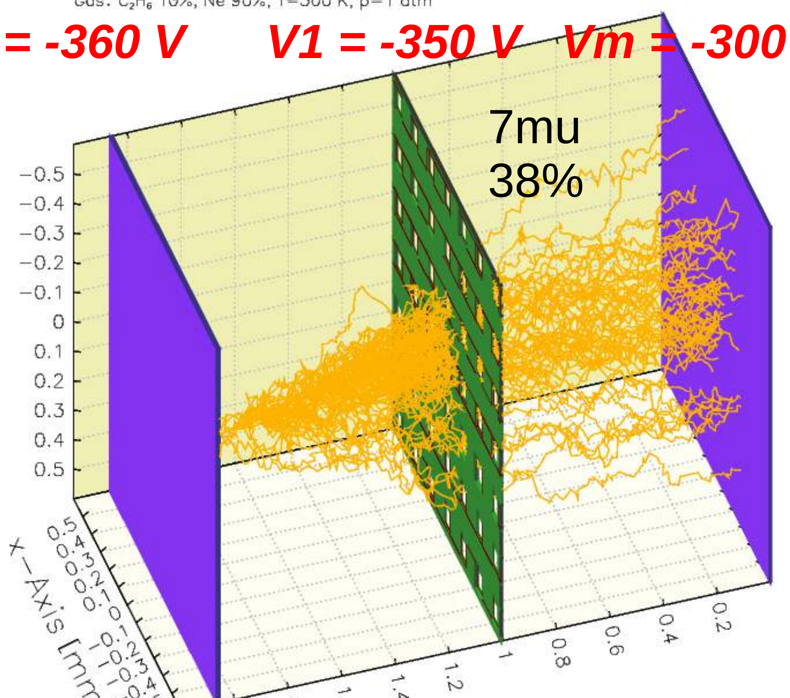
F= 10
64%

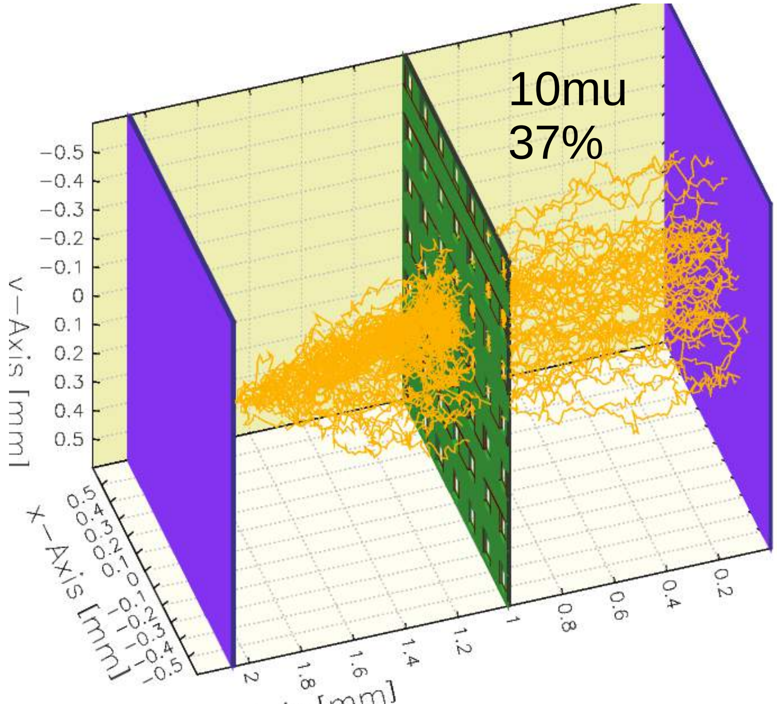


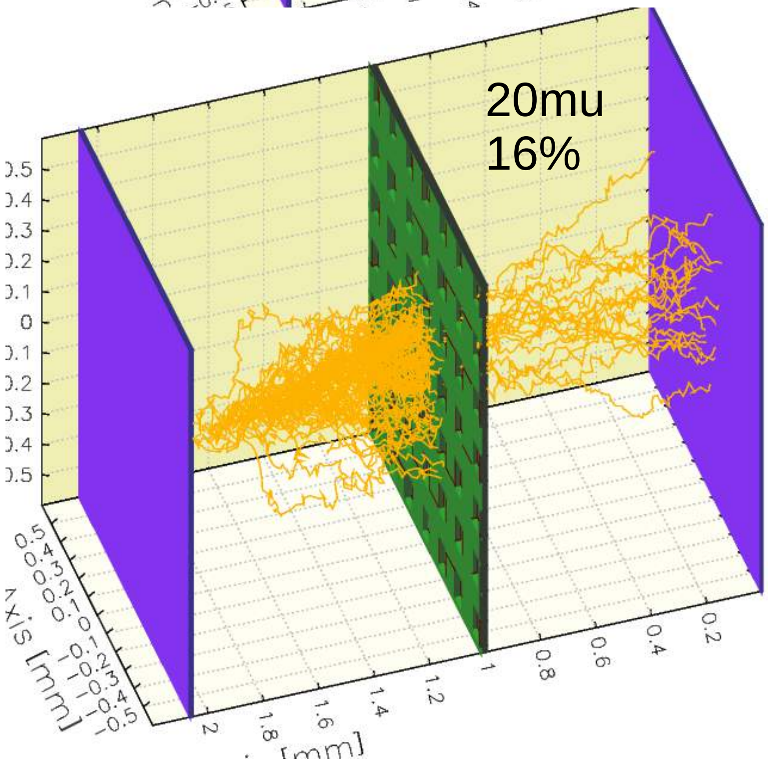
V2 = -510 V V1 = -500 V Vm = -300

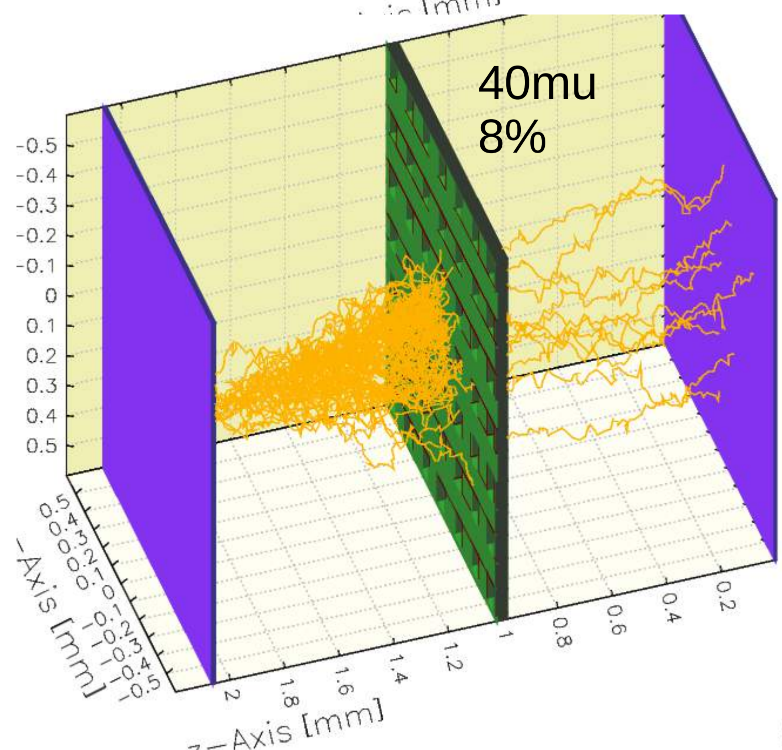
F= 20
74%

Changing thickness with const f=5 – Ne,C2H6(10%)









Changing thickness with const f=5 – Ne,C2H6(10%)